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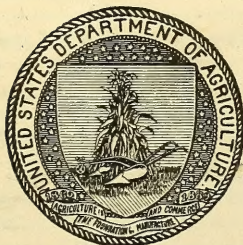
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A. D. MELVIN, Chief



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PROFESSIONAL PAPER

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THE CHEMICAL COMPOSITION OF LIME-SULPHUR ANIMAL DIPS.

By ROBERT M. CHAPIN, *Senior Biochemist, Biochemic Division.*

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The literature on the subject of lime-sulphur solutions is already voluminous. But even the ablest investigators have been handicapped by limitations in their methods of analysis, while some of the published work, especially in recent years, has been of such a character as to bring the whole matter into a state of confusion. Inasmuch as the writer has been able to develop some new methods of analysis^{1,2a} which appear in several ways superior to former ones, it has been a logical step to utilize these new methods in a general study of the composition of lime-sulphur solutions. The information so obtained appears to determine decisively some facts which previously could be only a matter of conjecture or at least only qualitatively studied, and others which have been the subject of dispute, although it very likely brings out little radically new. Lime-sulphur solutions are of considerable practical importance and precise information regarding them is of distinct value.

EXPERIMENTAL MATERIALS AND METHODS.

The general plan of investigation was necessarily simple, merely involving the preparation of solutions according to different formulas and under different conditions, with subsequent analyses and com-

^a The figures refer to the list of references at end of bulletin.

parison of results. The lime used was prepared from chemically pure calcium oxid by slaking and drying out, then passing through an 80-mesh sieve. Its content in available calcium oxid was determined by the phenol solution method of Lindet and Brasart.³ The sulphur used was sifted U. S. P. flowers, assumed without analysis to be sufficiently pure for the purpose.

The methods of analysis have been fully described in the previous papers referred to. For the sulphid-acid figure "Method B" was employed, while the sulphid-base figure was not directly determined, since it can be obtained with greater accuracy by algebraic addition of the sulphid-acid figure and the reaction figure. All determinations were performed in duplicate.

EFFECT OF STORAGE.

EXPERIMENT 1.

The first series of experiments, as it happened, was directed toward a study of the stability of lime-sulphur solutions during storage. A number of preparations made for another purpose had been partially analyzed when other matters interrupted. On resumption of the work it seemed best to repeat all the determinations previously executed. The results are given in Table 1, under Experiment 1.

The formulas employed were based on 100 parts of sulphur in all cases, while the lime is expressed in proportional parts available calcium oxid. The proportional parts of water given include both water added as such and the water of hydration of the lime. The lime and sulphur were thoroughly mixed dry in the container in which the solution was to be prepared—a 500 c. c. Kjeldahl flask. The desired amount of water, usually 200 c. c. was then added gradually with thorough mixing. The mixtures were brought to boiling under reflux in about five minutes, and only the period of actual boiling was counted. Shortly before the end of the boiling period, during which the flask was frequently shaken, a stream of illuminating gas washed through caustic-soda solution was introduced through a narrow tube passing down the condenser into the neck of the flask. The flask was partially cooled under these conditions by immersion in water, then the well-mixed contents were transferred to 4-ounce "sample oil" bottles, which were filled into the necks and sealed. When cold the bottles were thoroughly shaken to insure a uniform solution.

The results of Experiment 1 show that within the range of practice, no matter what the formula or conditions of preparation may have been, all lime-sulphur solutions stored after decantation from sediment will acquire a distinct negative reaction figure in course of time. Divers and Shimidzu⁴ qualitatively showed the reversibility of the reaction, simply stated: $\text{CaS}_x + 2\text{H}_2\text{O} \rightleftharpoons \text{Ca}(\text{OH})_2 + \text{H}_2\text{S} + (x-1)\text{S}$. In Experiment 1 we evidently have quantitative data relative thereto. The course of the equation from left to right is a matter of hydrolysis and the reaction evidently will progress thus in all solutions until inhibited by the accumulation of hydrogen sulphid, provided the latter is not allowed to escape. The more dilute

the solution naturally the greater will be the degree of hydrolysis before equilibrium is reached. The free calcium hydroxid simultaneously produced reacts with the free sulphur or with polysulphur, and is thus removed from the sphere of action, the whole series of reactions therefore becoming irreversible.

According to the above hypothesis there should be a slight decrease of polysulphur and a slight increase of both monosulphur and thio-sulphate sulphur during storage. This is not consistently true of the concentrates of Experiment 1. On the contrary concentrates A to E, inclusive, suffer a distinct though slight decrease in thiosulphate figure. But the diluted solutions of samples C and E do give more positive indications of the correctness of the above view, though such slight differences can hardly be considered as of much significance in either direction. In this connection it seemed well to try the effect of the addition of calcium hydroxid to a dilute lime-sulphur solution.

TABLE 1.—*Effect of storage upon analytical figures; concentrates diluted to 8 volumes.*

Experiment No.	Sample No.	Formula: CaO:S:II ₂ O.	Time boiled.	Storage over sediment.	Storage decanted.	Storage diluted.	Reaction figure.	Thio-sulphate figure.	Sulphid-acid figure.	Poly-sulphur figure.
			Hours.	Days.	Days.	Days.				
1.....	A-1	40:100:513	1	3	0	0	-0.30	6.03	21.08	-----
	A-2			71	0	0	-0.30	5.90	21.28	40.62
	B-1			1	0	0	-0.35	6.52	23.69	-----
	B-2	45:100:514	1	1	63	0	-0.37	6.36	23.71	45.47
	C-1			1	0	0	-0.66	6.92	25.10	-----
	C-2			1	61	0	-0.17	6.87	24.65	44.37
	C-3	47.5:100:515.	1	1	0	74	-0.97	6.88	25.25	43.83
	D-1			1	0	0	+0.03	7.06	25.95	-----
	D-2			1	61	0	-0.13	6.91	25.94	43.61
	E-1	50:100:516	1	4	0	0	+0.06	7.14	24.81	-----
	E-2			4	62	0	-0.14	6.94	25.06	41.83
	E-3			4	0	94	-0.73	7.10	25.46	40.89
	F-1	45:100:514	0.5	2	0	0	-0.29	6.32	23.72	-----
	F-2			2	62	0	-0.15	6.42	23.49	45.78
	G-1			1	0	0	+0.26	5.74	21.42	-----
2.....	G-2	45:100:514	0.25	1	33	0	0.00	5.87	21.27	40.52
	G-3	Special.	-----	-----	-----	-----	+3.34	6.11	22.84	39.45
	R-1	Special.	-----	-----	-----	-----	-0.43	6.17	28.56	49.09
	R-2	Special.	-----	-----	-----	-----	-0.01	12.41	15.52	30.92

EFFECT OF LIME ADDED AFTER DILUTION.

EXPERIMENT 2.

To about 110 c. c. of sample G-2, which had been stored 27 days after dilution, was added slaked lime equivalent to about 2 grams calcium oxid, and the mixture was kept at room temperature in a filled and sealed bottle for 10 days. Each working day, except the last two, when it was left to settle, the bottle was placed in a shaking machine for several hours. The results of analysis are given in Table 1, under Experiment 2, sample G-3.

The changes in the analytical figures between samples G-2 and G-3 are entirely consistent. But it is interesting to note the extreme slowness with which calcium hydroxid reacts with calcium penta-

sulphid in cold dilute solution. Despite the intimate contact of the materials for 10 days and the high plus reaction figure at the end, the analytical figures for the various forms of sulphur were only slightly affected, and the value of x in CaS_x was reduced from 4.81 in sample G-2 only to 4.45 in sample G-3. Therefore for horticultural spraying purposes it appears that lime may be added to the diluted solutions shortly before use without seriously affecting the various sulphur compounds.

After completion of the preliminary experiments on the effect of storage, the main investigation could be undertaken on the effect produced by varying formulas and conditions.

EFFECT OF VARYING LIME-SULPHUR RATIO.

EXPERIMENT 3.

Here lime was the only variable, the amount of sulphur and water and the period of boiling being maintained constant. The concentrated solutions were prepared as described under experiment 1, and, in fact, the majority of them were the same samples, as shown by the identification letters. All determinations were made on freshly prepared dilutions of concentrates which had been stored not less than two months after decantation from sediment, except in case of sample G, stored for 33 days. The results are given in Table 2.

With increasing proportion of lime the percentage of thiosulphate sulphur increases throughout, but the parallelly increasing percentage of monosulphur, together with other analytical values, drops after passing Preparation D merely on account of deposition of polysulphid in crystalline form, as is well known to occur sometimes in preparations made with an excess of lime. Polysulphur reached its maximum value at the lime-sulphur ratio 0.45 in Preparation B, as did also total sulphid sulphur, although total sulphur continued to make a very slight further gain. But probably the most illuminating results are shown by the analytical ratio of total lime to total sulphur. Equal utilization of lime and sulphur begins with Preparation B, where the analytical ratio 0.450 comes out exactly the same as the formula ratio. An excess of sulphur over that ratio, as in Preparation A, produced no higher polysulphid and simply was not utilized. With increasing lime-sulphur ratio equal utilization of lime and sulphur continues certainly into the close vicinity of the ratio 0.500, though at that point results begin to be obscured by the deposition of crystals. But increased ratio means a lower polysulphid, as is clearly shown.

For each molecule of thiosulphate formed in the reaction there was produced an average of about 1.84 molecules of polysulphid. The individual variations from the average seem in no way to be consistently dependent upon variations in formula. This ratio will be discussed later.

TABLE 2.—Composition in grams per 100 c. c. ("per cent") and ratios of stored concentrates prepared under varying formulas and conditions.

Experiment No.	Preparation No.	Formula: CaO:S:H ₂ O.	Time boiled.	Thiosulphate sulphur.	H ₂ S sulphur.	Total monosulphur.	Polysulphur.	Total sulphid sulphur.	Total sulphur.	Total equivalent CaO. ^a	Analytical ratio. Total CaO Total S.	Value of x in M ₂ S _x .	Molecular ratio, $\frac{M_2S_x}{M_2S_2O_3}$.
			Hours.										
3.	A	40:100:513	1	3.02	0.04	2.73	10.43	13.16	16.18	7.35	0.454	4.82	1.81
	B	45:100:514	1	3.26	.05	3.04	11.67	14.71	17.97	8.09	.450	4.84	1.86
	C	47.5:100:515	1	3.52	.02	3.16	11.39	14.55	18.07	8.57	.474	4.60	1.80
	D	50:100:516	1	3.54	.02	3.33	11.20	14.53	18.07	8.89	.492	4.36	1.88
	E	60:100:519	1	3.56	.02	3.22	10.73	13.95	17.51	8.70	.508	4.33	1.80
4.	F	45:100:514	.5	3.79	.02	3.01	11.75	14.76	18.05	8.12	.450	4.90	1.83
	G	45:100:514	.25	3.01	.00	2.73	10.40	13.13	16.14	7.41	.459	4.81	1.81
5.	H	45:100:1014	.75	1.77	.05	1.61	6.10	7.71	9.48	4.37	.461	4.79	1.82
	I	45:100:264	.5+	2.38	.03	5.63	21.20	26.83	29.21	11.94	.409	4.77	4.74

^a Estimated by calculation from the results for the various forms of sulphur—not by direct determination.

The figures for hydrogen sulphid sulphur in themselves possess little significance from a quantitative point of view, the exact amount present depending upon variable factors. But the figures can be utilized to obtain a nearer approximation to the value of x in CaS_x than given in the table for the value in M₂S_x. If this form of sulphur is present only as free hydrogen sulphid, then the value for x in CaS_x of Preparation B becomes 4.92, while if all hydrogen sulphid is present as calcium hydrosulphid the value of x is raised to exactly 5.00. All the other preparations under Experiment 1 naturally give lower values.

The next undertaking was to determine the effect of varying the period of boiling.

EFFECT OF VARYING PERIOD OF BOILING.

EXPERIMENT 4.

Using the formula 45:100:514, which had shown the best utilization of both lime and sulphur in Experiment 3, concentrates were prepared, diluted, and analyzed exactly as described under Experiment 3, except in the period of boiling. The results are given in Table 2. With Preparations F and G is also to be included Preparation B, under Experiment 3, as the first member of the series.

Under the conditions of Experiment 4, boiling for 0.5 hour and for one hour produced practically identical results; that is, boiling for the shorter period appeared to produce as complete and perfect a reaction as possible, while boiling for a further half hour seemed to effect no material injury. The higher value for x in M₂S_x shown after 0.5 hour boiling is chiefly due to the less amount of hydrogen sulphid which happened to be present. Assuming free H₂S the value of x in CaS_x is 4.94, and assuming Ca(SH)₂ it is 4.98.

On the other hand, boiling for 0.25 hour was plainly insufficient. All percentages are lower and so is the value of x in M_2S_x , while the original reaction figure before storage was positive (Table 1).

Next came a study of the effect of varying the concentration at which the boiling was conducted.

EFFECT OF VARYING CONCENTRATION.

EXPERIMENT 5.

The concentrates were prepared as described for the previous experiments, and the results are given in Table 2. Preparation H was boiled only 0.75 hour since the odor of hydrogen sulphid had then become very strong and Experiment 4 had shown no essential difference between boiling for 0.5 and one hour. In case of Preparation I the ingredients made such a thick mixture that the flask was first heated for 0.75 hour in a boiling-water bath with frequent shaking and constant passage of alkali-washed illuminating gas, then the preparation was finished by boiling for 0.5 hour in the usual way. Preparation B, Experiment 3, is also to be included in this group, being the middle member of the series.

The more dilute preparation, Preparation H, showed results entirely comparable with Preparation B (Experiment 3). The apparently lower value for x in M_2S_x is due to the relatively larger amount of hydrogen sulphid. Assuming free H_2S , the value of x in CaS_x is 4.94; assuming $Ca(SH)_2$ it becomes 5.09.

In case of the more concentrated preparation, Preparation I, there is evident a striking rise in the molecular ratio of polysulphid to thio-sulphate. This well-known phenomenon in the preparation of highly concentrated solutions has been ascribed by Van Slyke et al.⁵ to the decomposition of calcium thiosulphate into calcium sulphite and sulphur. Notwithstanding the additional amount of sulphur thus rendered available the value of x in M_2S_x suffers a distinct drop in comparison with Preparations B and H, rendered more noticeable if calculations are made to actual CaS_x . Parallely, Küster and Heberlein⁶ found the value of x in Na_2S_x to be highest at a certain optimum concentration, decreasing when the solution was made either more concentrated or more dilute.

A question which here naturally arises is whether there is any more complete utilization of the raw materials at one concentration than at another. This can be answered approximately by comparing the weights of monosulphur in Preparations H, B, and I. Letting W stand for the weight of monosulphur, and v for the volume of dissolved substance, the three following equations hold:

- (1) for Preparation H; $W=.0161 (v+1014)$
- (2) for Preparation B; $W=.0304 (v+ 514)$
- (3) for Preparation I; $W=.0563 (v+ 264)$

In these three equations v may be taken as practically a constant quantity. Therefore eliminating v in equations 1 and 2 and solving for W we have $W=17.1$. In the same way from equations 1 and 3 we have $W=16.9$, and from equations 2 and 3, $W=16.6$. Accordingly the utilization of the raw materials appears to become slightly less complete with increasing concentration.

OCCURRENCE AND RELATIONS OF CALCIUM SULPHITE.

While Van Slyke and his coworkers undoubtedly established the presence of calcium sulphite as a frequent ingredient in the sediment from lime-sulphur solutions certain points seemed to call for additional investigation. Particularly was it desired to ascertain if lessened solubility of calcium thiosulphate in liquids heavily loaded with other calcium salts might deserve consideration.

EXPERIMENT 6.

First, 50 c. c. of Preparation I was boiled for five minutes under gas and reflux with 5 grams of calcium sulphite. After several days standing a 15-volume dilution gave a thiosulphate figure of 2.01 against a figure of 2.47 for a similar dilution of the original material. The other analytical figures showed no change except very slight increases attributable to loss of water.

Second, a portion of Preparation H was treated in the same way. A 5-volume dilution prepared the following day gave a thiosulphate figure of 6.98 against a figure of 5.53 for a similar dilution of the original material. Boiling in the same way for 15 minutes longer raised the figure to 8.54.

Third, about 100 c. c. of Preparation I with 10 grams calcium thiosulphate in a filled and sealed bottle was mechanically shaken several hours at room temperature. A 15-volume dilution of the supernatant liquid had a thiosulphate figure of 5.42 against the figure of 2.47 for a similar dilution of the original material. A clear decanted portion of the concentrate thus treated was then heated in a flask provided with a vertical air condenser for one hour in a boiling-water bath. Much sediment appeared. After settling for several days a 15-volume dilution had a thiosulphate figure of 2.91. The other analytical figures showed no significant differences from the corresponding figures of the original untreated Preparation I. The insoluble residue produced was washed with cold distilled water until free from the yellow color of polysulphids. A portion suspended in water showed a slightly alkaline reaction with phenolphthalein, and absorbed a large quantity of strong iodine solution. During addition of iodine solution the odor of sulphur dioxide became at one stage very distinct. After excess of iodine had been added and then removed by sodium thiosulphate the resulting liquid was strongly acid to methyl orange, all of which reactions combined constitute conclusive proof of the presence of sulphites.⁷

By Experiment 6 the equilibrium of the reaction $\text{CaS}_2\text{O}_3 \rightleftharpoons \text{CaSO}_3 + \text{S}$ is controlled by both temperature and concentration of the solution. Highly concentrated solutions can dissolve in the cold much more calcium thiosulphate than naturally occurs in them, but on heating the above reaction progresses from left to right. On the other hand,

calcium sulphite added to boiling dilute solutions reacts with polysulphur and forms thiosulphate. Therefore in practice there must be a fairly definitely fixed concentration below which sulphite will not be permanently formed in significant amount during the preparation of lime-sulphur solutions, lying somewhere between 3.04 and 5.63 per cent of monosulphur. It seemed desirable to fix this critical concentration a little more closely.

EXPERIMENT 7.

Preparations of intermediate concentration were prepared in the usual manner except that a decided excess of lime was used and boiling continued for 1.25 hours or longer. Preparation K was found to contain 3.33 per cent monosulphur with a ratio $M_2S_x : M_2S_2O_3 = 1.82$. Preparation L contained 3.95 per cent monosulphur with a ratio $M_2S_x : M_2S_2O_3 = 3.79$.

By this experiment, in addition to which further tests did not seem worth while, the critical concentration lies between 3.33 and 3.95 per cent monosulphur, which, assuming that one-sixth of the sulphur is converted to monosulphur, corresponds in the formula to the use of respectively 20 and 23.7 grams of sulphur per 100 c. c. of finished solution.

RATIO OF POLYSULPHID TO THIOSULPHATE.

For many years it has been unquestioned that the primary reaction between lime and sulphur in water is: $3Ca(OH)_2 + (2x+2)S = 2CaS_x + CaS_2O_3 + 3H_2O$, which equation of course calls for a ratio of 2 between the molecules of polysulphid and thiosulphate produced. The ratios actually obtained in Experiment 2, as already noted, all fell considerably below the theoretical figure. Part of the discrepancy may be ascribed to hydrolysis with subsequent loss by volatilization of the hydrogen sulphid, and part to oxidation, since the conditions of the experiments were only such as to minimize, not absolutely exclude, contact with air. It seemed desirable to ascertain how nearly the theoretical ratio could be reached under more favorable conditions.

EXPERIMENT 8.

A fifth of the formula 45:100:1014 was charged into a stout bottle, the small remaining space being filled with washed illuminating gas, and the tightly stoppered bottled was attached to a shaking machine and immersed in a water bath. After heating for 0.5 hour the originally cold bath had reached a temperature of 80° C. and the liquid in the flask had become decidedly yellow. Further heating rapidly deepened the color until after 0.75 hour from the start a temperature of 95° C. was reached, after which the bath was maintained at 90° to 95° C. for one hour longer. The bottle was then removed from the bath and cooled in running water. When it was opened the odors of illuminating gas and of hydrogen sulphid were strong. A 4-volume dilution was made the next day and analysis gave the molecular ratio $M_2S_x : M_2S_2O_3 = 1.89$. (Preparation M.)

To eliminate the disturbing effect of hydrolysis which had evidently occurred, Preparation N was made by charging 20 grams sulphur and slaked lime equivalent to 9 grams available calcium oxid into a 4-ounce sample oil bottle, which was then filled with water and sealed. For some weeks the bottle was shaken by machine several hours each working day, but the action was so slow that finally it was simply given a brief shaking by hand once or twice a day. After 42 days a sample of the clear liquid, diluted to 2 volumes, showed the molecular ratio $M_2S_x : M_2S_2O_3 = 1.92$.

The last preparation suffered a slight exposure to air while the necessary degree of dilution for analysis was being ascertained. To get further light on the possibilities Preparation O was similarly made, but using only 10 grams sulphur and employing a slight calculated excess of caustic soda solution instead of lime. In 5 days the sulphur was entirely dissolved, and on the next day a 4-volume dilution showed the molecular ratio $M_2S_x : M_2S_2O_3 = 1.93$. The dilution had been prepared by pipetting 25 c. c. into a 100 c. c. volumetric flask about half full of water, then making to the mark. The diluted solution was fitted into 15 c. c. glass-stoppered bottles, one of which was used for each test. Freshly boiled water was used for the original preparation and for the dilution.

From Experiment 8 it is evident that the fundamental reaction between lime and sulphur is parallel to that between caustic soda and sulphur and it must be assumed that two molecules of polysulphid are produced for each molecule of thiosulphate. The analytical methods are not known to be at fault except in a minute error of end-point, arising from the necessity of obtaining the sulphid-acid figure by subtraction. The chief cause of the failure to reach the theoretical ratio must, therefore, be oxidation during the manipulation of the solutions. An oxidation of 1 per cent of the monosulphur to thiosulphate by calculation would produce a drop in the ratio from 2.00 to 1.94.

LOWER POLYSULPHIDS; EFFECT OF EXCESS OF LIME.

The composition of the crystalline polysulphid which sometimes forms in a solution prepared with excessive lime has received considerable previous study with conflicting results.⁸ It seems, however, to have been proved to be a basic polysulphid which is decomposed when treated with water into calcium hydrate and a soluble calcium polysulphid that was first stated by Schöne to be tetrasulphid. For present study the composition of the crystals themselves is immaterial, since we are only concerned with polysulphids in solution. So far as work subsequent to Schöne has covered the question it has only served to confirm his observations and to strengthen the hypothesis that tetrasulphid is the lowest polysulphid ever occurring in a lime-sulphur solution. Only the following experiment was, therefore, thought necessary.

EXPERIMENT 9.

Preparation P, originally intended to follow Preparation E in Experiment 3, was made on the formula 70:100:521, boiling for one hour. After standing

over sediment for 74 days, during which time a considerable quantity of crystals formed, the supernatant liquid was decanted and analyzed. The bottle was then filled with water, the sediment broken up, and the corked bottle mechanically shaken for several hours. The supernatant liquid was in turn decanted, and the sediment, which still contained orange crystals, was once more extracted in the same way. The values of x in M_2S_x were found as follows: Original solution, 4.33; first extract, 4.17; second extract, 4.04. Using the thiosulphate figures as an index of the amount of mother liquor remaining in each extract gave $x=3.75$ for the CaS_x of the original crystals and $x=3.97$ for the crystals remaining after the first extraction, though these figures must of course be regarded as only approximations.

Experiments 1 and 3 had seemed to show that the use of an excess of lime necessarily produced in the fresh preparations a distinctly plus reaction figure and a considerable proportion of tetrasulphid. But the preparations there made had been rather intimately mixed with their sediments during and after cooling under conditions not entirely comparable to the ordinary. Accordingly, further experiments were undertaken.

EXPERIMENT 10.

Preparation K, already mentioned under Experiment 7, made with excessive lime, after boiling for 1.5 hours, was allowed to cool slightly under gas, mixed, allowed to settle a moment, and then decanted from most of the sediment into a 200 c.c. stout flask which was filled almost full and stoppered. The flask was immersed in a water bath set on the steam bath and left at rest for about 0.75 hour at 70° to 75° C. The still slightly cloudy solution was decanted through cotton, through which it filtered perfectly clear. After about two hours, when the solution had become thoroughly cold, an 8-volume dilution showed a reaction figure of -0.02 and a value of x in $M_2S_x=4.40$.

Sample Q was prepared in the regular apparatus with excess lime, but boiled for only 0.25 hour. After cooling five minutes under gas with frequent shaking sediment and all were brought onto a cotton filter, except for a portion of mixed sediment and liquid separately preserved. In about three hours crystals had formed in the sediment of the unfiltered material, but none appeared then or after several days in the filtered solution. A portion of the latter, about three hours after preparation, was diluted to eight volumes, and the diluted solution showed a reaction figure of $+0.47$ with a value of x in M_2S_x of 4.77. The concentrate contained 2.95 per cent monosulphur.

As respects reaction figures, it is evident that a preparation carrying excess of lime, if cooled in intimate contact with its sediment, will very naturally possess a plus reaction figure. But if the preparation is allowed to settle in the heat, undissolved calcium hydrate is rapidly deposited and so removed from further activity, while the small amount remaining in solution soon disappears through reaction with pentasulphid. Hydrolysis will finally produce a minus reaction figure. The latter conditions of course more nearly parallel those prevailing in practice.

The marked difference in the values for x in CaS_x shown by Preparations P and Q is also of interest. It seems futile to speculate on what particular polysulphid may be the immediate product of

the reaction between lime and sulphur. To the writer it appears logical to believe that in a boiling solution containing both lime and sulphur, that is, an unfinished solution like Preparation Q, there is little but pentasulphid present. If any lower polysulphid really is the first product, it apparently at once takes up more sulphur and becomes pentasulphid. Especially is this likely to be true from the well-known fact that hot solutions can dissolve notably more sulphur than corresponds to the formula CaS_5 . If the foregoing is granted, then it follows that tetrasulphid present at the end has mainly resulted from the secondary reaction of pentasulphid with lime.

HIGHER POLYSULPHIDS; EFFECT OF OXIDATION.

When a lime-sulphur solution is exposed to air, calcium polysulphid is oxidized to calcium thiosulphate and sulphur. It seems rational that in the presence of this nascent sulphur calcium polysulphid remaining undecomposed should pass to the highest possible stage of sulphurization, and that data thus obtained regarding the highest polysulphid of calcium existing in solution should be much more trustworthy than those derived from the rather dubious method of Auld⁸ which led him to infer the existence of polysulphids much higher than the pentasulphid.

EXPERIMENT 11.

A portion of a dilution prepared about two months previously from a concentrate of high lime-sulphur ratio was vigorously shaken in a flask connected without exit tube with a small gasometer of pure oxygen. A considerable quantity of oxygen was absorbed while the solution remained perfectly clear, during which stage the nascent sulphur was evidently wholly entering combination to produce higher calcium polysulphids than were originally present. At a certain point, however, the solution suddenly became opalescent, and thereafter rapidly increased in turbidity. Treatment with oxygen, which altogether occupied but a brief time, was stopped when a considerable quantity of free sulphur appeared present, and the solution was transferred to a well-filled and sealed bottle. Vigorous shaking coagulated the sulphur, but some air had become entangled, so it was necessary the next day to filter rapidly through a loose plug of cotton, after which both the original solution (sample R-1) and the oxidized solution (sample R-2) were analyzed. The titration results are given in Table 1.

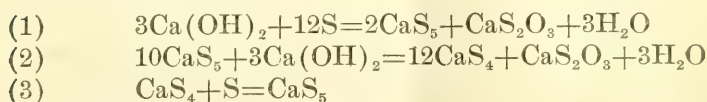
The value of x in the M_2S_x of sample R-1 was, therefore, 4.44, while after oxidation the value of x in CaS_x for sample R-2 rose to 4.99. Another experiment in which a very slow current of air was bubbled for a long time gave exactly the same figure. Therefore it is plain that a lime-sulphur solution as applied in practice never contains a calcium polysulphid higher than the pentasulphid. On the other hand any lower polysulphid present in the solution before application probably becomes pentasulphid through free contact with air soon after if not during the process of application.

It is interesting to note the change in reaction figure between samples R-1 and R-2. The change is, of course, perfectly logical, for the hydrogen sulphid which produces the negative reaction figure becomes simply sulphur and water upon oxidation. In deducing the equation to express oxidation, it is accordingly necessary in this case to employ the sulphid-base figures and not the sulphid-acid figures. The change of sulphid-base figure from sample R-1 to sample R-2 is $28.13-15.51=12.62$ loss, which, according to the accepted equation $\text{CaS}_x+3\text{O}=\text{CaS}_2\text{O}_3+(x-2)\text{S}$, should be balanced by a gain of one-half as much, or 6.31, in the thiosulphate figure. The actual gain in the thiosulphate figure in the experiment was 6.24, which is in reasonable agreement.

CONCLUSIONS.

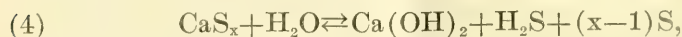
The reactions which determine the composition of lime-sulphur solutions, besides being rather numerous, are some of them reversible, the points of equilibrium varying according as the solution is hot or cold, dilute or concentrated, or exposed to the influence of other varying conditions. Under such circumstances the only way in which laboratory studies can be of practical value is by so thoroughly establishing the fundamental principles involved and the effect of varying conditions upon the relative importance of such principles as to afford a sound basis for reasoning.

It appears that when lime and sulphur are boiled with water, ignoring unessential and hypothetical intermediate compounds, the following reactions occur:

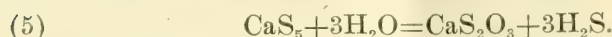


Only when substantially all free sulphur has been dissolved will equation 2 become operative or equation 3 fail to hold all polysulphid substantially up to the pentasulphid.

All lime-sulphur solutions are subject to hydrolytic decomposition according to the equation:

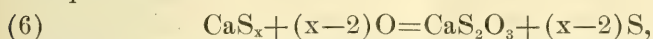


the pressure of the reaction from left to right increasing with rise of temperature. Whether or not hydrogen sulphid can escape, the remaining products on the right-hand side react according to equation 1, giving as final result, in case of CaS_5 ,



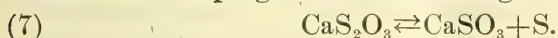
Thus all solutions are in equilibrium only when they contain a certain excess of hydrogen sulphid, the amount being dependent upon the temperatures and concentrations of the solutions.

Solutions exposed to air are oxidized, as is usually represented by the equation:



although it is possible that, as propounded by Divers and Shimidzu, the immediate action is an oxidation of the hydrogen sulphid liberated according to equation 4.

Above a certain concentration of the hot solution, which appears to lie between 3.33 and 3.95 per cent of monosulphur, the following reaction tends to progress from left to right:



A well-boiled solution, not originally made with an excess of lime, can never under any circumstances possess a plus reaction figure—that is, it can not contain calcium hydroxid in excess of monosulphur. If originally made with an excess of lime or if not boiled long enough, excess lime is at first present in solution. But if such a preparation be allowed to stand quietly and cool off in the cooking vat, the indications are that the undissolved lime soon settles down, while the small amount of dissolved lime rapidly reacts with polysulphur according to equation 2, so that in this case, also, unless the cooled solution is again stirred up with the sediment, a plus reaction figure can never be present in the end. But such a solution will naturally contain a notable amount of tetrasulphid.

As regards the period of boiling, it is not improbable that the time should be increased with increasing concentration. Lime is but little soluble in the solution at any stage, and it probably must dissolve before it can react with the sulphur. It would seem, therefore, that a longer time must necessarily be required in a given volume for a large quantity of lime to enter successively into solution and into reaction than for a small quantity.

As regards the effect of degree of concentration, in addition to the decomposition of thiosulphate which has been noted, the indications are that with increasing concentration the utilization of both lime and sulphur possibly becomes less nearly complete, and also that the polysulphids formed possibly contain a somewhat less proportion of pentasulphid. But the apparent effect might have been produced simply by insufficient boiling, and in any event it is of no material significance in comparison with the practical importance of putting out proprietary preparations in highly concentrated form.

Finished solutions, if stored over sediment which contains free lime, will naturally tend to maintain a plus reaction figure and will undergo changes attributable to the slow progress of reactions 1 and 2. If decanted from sediment and preserved from access of air, only two slight changes are noticeable; first, the progress of equation 5 until a certain concentration of hydrogen sulphid is reached, when equilibrium is established according to equation 4;

second, an apparent slight drop in the thiosulphate figure, for which no explanation is offered, since the phenomenon appeared too quantitatively insignificant to warrant special investigation. Both changes, in fact, are so slight as to be entirely negligible for practical purposes and under ordinary conditions.

For the actual preparation of lime-sulphur solutions equations 1, 2, and 3 call for the use of 43.7 parts of available calcium oxid to 100 parts sulphur. That the laboratory experiments did not precisely check this theoretical ratio is attributable solely to the decompositions represented by equations 5 and 6. The decomposition represented by equation 5 is independent of the formula employed and in no way changes the relative proportions of primary ingredients called for; that is, equation 5, following the postulated escape of hydrogen sulphid, produces neither free lime nor free sulphur, and leaves the solution neutral. There remains then only the matter of oxidation to be considered. But that is a surface action solely, and considering the enormous advantage in the ratio of volume to surface possessed by even moderate-sized cooking vats over laboratory apparatus, it approaches a negligible factor. Therefore the theoretical ratio becomes the actual ratio which should be followed in practice, provided only the concentration is not sufficient to allow equation 7 to progress from left to right. The formation of sulphite becomes a significant factor when the formula employs somewhat more than 20 parts of sulphur per 100 volumes of finished solution. For a number of reasons the writer believes that it will be generally inadvisable to try for a much higher degree of concentration in "homemade" solutions. Certainly in such solutions no allowance should be made for the formation of sulphite by increasing the ratio of lime to sulphur, as the extent of the decomposition is too dependent on the degree of concentration and length of boiling after the solution is otherwise complete. Attempts to make more concentrated solutions are attended by greater difficulty in manipulating the thick liquid and in avoiding loss by boiling over, and moreover involve more loss of the finished solution in the wet sludge, especially since the volume of sludge is increased by deposition of calcium sulphite.

Nowhere is there evidence of the existence in cold solutions of more sulphur, either free or combined, than corresponds to the formula CaS_5 . On the other hand, a properly prepared homemade solution will contain at most but a small amount of tetrasulphid. It will also contain a very small amount of hydrogen sulphid, some of which may possibly be in the form of calcium hydrosulphid. While rigidly scientific proof that the two apparently definite proportions of, respectively, four atoms and five atoms of sulphur to one atom of calcium may not, in fact, arise from mixtures of lower and higher

polysulphids is perhaps lacking, it is certainly true that all available evidence points to the existence of only those two.

The methods of analysis have proved to be adequate in scope and accuracy, as well as practical. Working in the ordinary way with flasks and pipettes the analyst apparently will not recover from a concentrate more than 99 per cent of the monosulphur, which indicates a recovery of 99.75 per cent of the polysulphur, or 99.6 per cent of the sulphid sulphur, figuring on pentasulphid only. The loss arises chiefly from oxidation during manipulation of the solutions and may be reduced only by manipulating in an atmosphere of some inert gas.

PRACTICAL APPLICATIONS.

It will be a logical concluding step to deduce from the data here presented a working formula for the preparation of lime-sulphur solutions. The subject has been dealt with by a number of investigators primarily interested in the preparation of such solutions for horticultural spraying purposes. Some of the formulas so developed seem to have given entire satisfaction for the purpose for which they were intended and the dilutions at which the resulting products should be employed under various conditions have become so well established that any change in formula would be of doubtful practical benefit. It is quite otherwise with solutions intended primarily for the purpose of dipping cattle and sheep. The formulas in use are those prescribed by the Bureau of Animal Industry many years ago when uncertainty regarding possible chemical reactions and possible effects of the resulting compounds upon both animals and parasites very properly led to the use of formulas which should be certain and safe, even if somewhat uneconomical. The formula here to be suggested is proposed therefore solely for use as an animal dip. It may be termed the "8-18-10" formula; that is, 8 pounds of high grade commercial quicklime, 18 pounds fine sulphur (either flowers or flour) with somewhat more than 10 gallons water, boiled to a volume of 10 gallons at the finish. The time of actual boiling should be one hour. The theoretical ratio between lime and sulphur will be met by this formula if the lime is 98.3 per cent pure, therefore the formula as given is appropriate for preparing a solution for dipping sheep where any chance of an excess of lime must be avoided. If commercial hydrated (not air-slaked) lime is used the amount should be increased nearly one-third, say to 10.5 pounds. For dipping cattle the formula may be used on the basis of available calcium oxid if the analysis of the lime is known, or if not known the lime may safely be raised to 8.5 pounds, corresponding to 92.5 per cent available calcium oxid, possibly even to 9 pounds. The manipulation of the materials in the actual process of preparation has been described in a recent publication from the Bureau.⁹

The finished solution, drawn off from the sediment, should theoretically contain 18 per cent (grams per 100 c. c.) of sulphid sulphur, but probably will contain somewhat less. It is, therefore, appropriate for dipping sheep at a dilution of 1 volume of concentrate to 9 or 10 volumes of water, and for cattle at a dilution of 1 volume of concentrate to 7 or 8 volumes of water. But in any event, since baths lose strength during dipping, it is very desirable to keep them at all times under control by means of a "field test."¹⁰

The particular advantages of the above formula are, first, that it closely approaches the theoretical ratio, making allowance for impurities; second, it is as concentrated a product as can be prepared without conversion of thiosulphate to sulphite; and third, the figures are easily remembered and readily converted into the quantities of ingredients necessary to prepare a batch of any desired size.

In deducing a formula for the preparation of highly concentrated proprietary solutions it is evident that the manufacturer must make a few trial runs with plenty of sulphur in order to establish the conditions which will uniformly yield the product he desires, analysis of which will then inform him by how much he may safely reduce the sulphur to allow for the formation of sulphite.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 452

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief



Washington, D. C.

PROFESSIONAL PAPER

December 18, 1916

THE CHEMICAL COMPOSITION OF AMERICAN GRAPES GROWN IN THE CENTRAL AND EASTERN STATES.

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INTRODUCTION.

This report on the composition of native American grapes is supplementary to that published as Bureau of Chemistry Bulletin 145,¹ which contains a general statement of the plans of the work. Although final opinion as to the range in chemical composition of the different varieties of grapes grown in various districts may require more study, the values commonly found are indicated by the results given in these two reports.

EXTENT OF INVESTIGATION.

Fewer samples were handled at the Sandusky and Charlottesville laboratories during the season of 1911 than in the two previous years, but care was taken to secure representative samples of the varieties analyzed. The field work in 1912 was devoted to other questions than variety examinations.

In 1913 the work was largely transferred to new territory and to districts not adequately covered in previous years. The collection and analysis of samples were limited to samples from New Jersey and New York for table and wine grapes and to samples of the

¹ Alwood, William B. *Enological Studies*, No. 4. The Chemical Composition of American Grapes Grown in Ohio, New York, and Virginia. U. S. Dept. Agr. Bur. Chem. Bul. 145. 1911.

rotundifolia grapes from North Carolina. In New Jersey the territory about Vineland and Egg Harbor was fairly well covered, and representative samples were collected and sent to the food and drug inspection laboratory at Philadelphia, where they were analyzed. In New York the region about Keuka Lake was covered and representative samples of table and wine grapes were collected and sent to the food and drug inspection laboratory at Buffalo, where they were analyzed. Further collections in New York were made of the Concord variety from the Chautauqua district. In this district and the adjacent northwestern part of Pennsylvania are located the largest grape-juice factories in the world; they use only Concord grapes for making grape juice.

During this investigation samples of every variety of grapes found in cultivation in the territory covered have been taken purposely because the available data on the composition of American native grapes were very inadequate.

Up to the present time, of the many varieties of grapes put out by the plant propagators, only a few have proved sufficiently valuable to warrant extensive cultivation. Yet it is important in a general investigation to make a fairly complete examination of all varieties found in cultivation until sufficient information as to their composition is available from which to obtain a basis for more discriminating work.

COLLECTION OF SAMPLES.

The sampling in 1911 was done almost wholly by persons employed temporarily by the Bureau of Chemistry and in a few instances by volunteer assistants. These assistants lived in the locality where the samples were taken and were engaged for this work because of their knowledge of the varieties. Every precaution was taken to secure samples which represented the average of the crop. The preparation and treatment of the samples during analysis were the same as described in Bulletin 145.²

The sampling in New Jersey and in the Keuka district in New York in 1913 was done by a member of the Bureau of Chemistry who personally visited the growers and collected samples of ripe fruit typical of each variety and crop. The samples reached the laboratory in good condition in both cases.

The sampling of Concord grapes in the Chautauqua district in 1913 was done at one of the large grape-juice factories. Certain crops were sampled six times between October 10 and 21 and in each case average fruit was taken. Care was observed to select crops which represented the different soil formations of the district. Eight crops were sampled on each date and in every instance a composite of these

² Ibid, pp. 9-11.

samples was made and analyzed. Analyses of 34 individual samples were also made.

The samples taken in North Carolina were selected in the vineyards by J. H. Jeffries, superintendent of the Pender Experiment Farm, which is owned and operated by the North Carolina State Board of Agriculture. Mr. Jeffries kindly undertook this work and sent the samples to Raleigh, where they were analyzed. Dr. B. W. Kilgore, chief chemist for the State Board of Agriculture at Raleigh, furnished laboratory room, apparatus, etc., and gave every assistance possible.

CHEMICAL COMPOSITION OF GRAPES EXAMINED.

The data represented in Tables 1 and 2 are arranged by localities, and the average, maximum, and minimum results are given when more than one sample was taken for each locality; a total average of all the analyses of each variety is given with maximum and minimum results as to solids, sugar, and acid on all the samples of any given variety examined. The specific gravity determined by a pycnometer at 15.6° C. is given individually for all single samples and the average is given where two or more samples are recorded for any locality. The determinations as to composition are given in grams in 100 cc of expressed juice.

TABLE 1.—Composition of American native grapes; average, maximum, and minimum data.

[Results stated in grams per 100 cc of expressed juice.]

SAMPLES FROM OHIO, NEW YORK, AND PENNSYLVANIA, 1911; EXAMINED AT SANDUSKY, OHIO; EOFF AND SHERWOOD, ANALYSTS.

Variety and locality.	Num- ber of sam- ples.	Brix.	Total solids.			Sugar-free solids.			Sugar as invert.			Acid as tartaric.		
			Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.
BACCHUS.														
Kelleys Island, Ohio.....	2	20.4	1.0852	22.15	21.02	3.36	3.58	3.14	18.79	20.14	17.44	1.174	1.282	1.065
Geneva, N. Y.....	1	19.7	1.0811	21.07		3.64			17.43			1.702		
Averages, limits, and totals.....	3	20.2	1.0838	21.79	21.02	3.45	3.64	3.14	18.34	20.14	17.43	1.317	1.702	1.065
CATAWBA.														
Kelleys Island, Ohio.....	6	20.3	1.0800	22.36	21.52	2.63	2.85	2.46	19.73	20.68	19.06	.732	.810	.660
Middle Bass, Ohio.....	3	20.2	1.0808	22.56	21.78	2.21	2.28	2.14	20.34	21.31	19.57	.595	.630	.570
North Bass, Ohio.....	12	20.6	1.0887	23.07	21.49	2.17	2.58	1.84	20.90	22.53	19.35	.646	.886	.518
Sandusky, Ohio.....	2	19.6	1.0780	20.26	20.83	2.06	2.10	2.01	18.20	18.73	17.67	.787	.802	.772
Venice, Ohio.....	5	20.4	1.0871	22.65	21.49	2.62	2.78	2.27	20.03	21.19	18.73	.874	1.005	.713
Geneva, N. Y.....	1	18.1	1.0755	19.60		1.96			17.64			.892		
Averages, limits, and totals.....	29	20.3	1.0855	21.81	19.60	2.33	2.58	1.84	20.15	22.53	17.64	.716	1.005	.518
CLINTON.														
Dover, Ohio.....	2	23.3	1.1010	26.31	25.99	3.40	3.42	3.38	22.91	23.24	22.57	1.184	1.222	1.155
Huron, Ohio.....	1	21.9	1.0925	24.07		2.99			21.08			1.140		
Venice, Ohio.....	1	24.3	1.1036	26.99		4.39			22.60			1.312		
Vermilion, Ohio.....	1	20.0	1.0857	22.28		3.68			18.60			1.036		
Averages, limits, and totals.....	5	22.6	1.0968	25.19	25.99	3.57	4.39	2.99	21.62	23.24	18.60	1.173	1.312	1.036
CONCORD.														
Kelleys Island, Ohio.....	1	17.5	1.0738	19.16		2.00			17.16			.503		
Middle Bass, Ohio.....	3	18.9	1.0794	20.61	19.86	1.97	2.36	1.76	18.65	18.92	18.10	.420	.420	.420
North Bass, Ohio.....	2	17.6	1.0728	18.88	19.05	1.97	2.41	2.24	16.56	16.81	16.30	.668	.735	.600
Put in Bay, Ohio.....	1	18.5	1.0781	20.28		2.45			17.83			.510		
Venice, Ohio.....	2	19.8	1.0833	21.64	22.86	2.33	2.47	2.18	19.31	20.39	18.23	.567	.600	.473
Vermilion, Ohio.....	2	18.0	1.0745	19.34	19.55	2.38	2.56	2.20	16.96	16.99	16.93	.518	.533	.503
Michigan.....	1	18.2	1.0756	19.63		2.27			17.36			.578		

Brocton, N. Y.	6	19.3	1.0807	20.85	21.31	20.70	2.28	2.55	2.10	18.68	19.05	18.28	.699	.772	.638
Fredonia, N. Y.	6	19.3	1.0727	18.87	19.68	18.40	2.85	3.20	2.29	16.01	16.87	15.41	.682	.750	.518
Geneva, N. Y.	1	18.2	1.0771	20.02	.....	.....	2.30	.....	.....	17.72	.....	.....	.638	.....	.....
Westfield, N. Y.	1	19.9	1.0841	21.86	.....	.....	2.02	.....	.....	19.84	.....	.....	.618	.....	.....
North East, Pa.	8	18.4	1.0753	19.55	21.38	17.69	2.52	3.06	1.71	15.80	18.67	15.07	.643	.735	.420
Averages, limits, and totals.	34	18.5	1.0768	19.93	22.86	17.69	2.41	3.20	1.71	17.53	20.39	15.07	.612	.772	.420
DELAWARE.															
Kelleys Island, Ohio.	1	22.7	1.0998	25.99	.....	.....	2.61	.....	.....	23.38	.....	.....	.510	.....	.....
Middle Bass, Ohio.	6	24.8	1.1080	28.12	29.33	27.01	2.50	3.05	1.98	25.62	26.85	24.34	.519	.548	.503
North Bass, Ohio.	2	23.2	1.1066	26.20	26.62	25.78	2.29	2.47	2.10	23.92	24.15	23.68	.676	.683	.668
Sandusky, Ohio.	2	23.9	1.1044	27.20	28.25	26.14	2.73	2.92	2.54	24.47	25.33	23.60	.563	.585	.540
Venice, Ohio.	2	22.9	1.0933	25.11	25.75	24.46	2.74	2.79	2.68	23.12	24.46	21.78	.582	.600	.563
Vermilion, Ohio.	1	20.8	1.0899	23.38	.....	.....	2.50	.....	.....	21.08	.....	.....	.525	.....	.....
Fredonia, N. Y.	2	18.3	1.0767	19.91	20.55	19.26	2.47	2.59	2.35	17.44	17.96	16.91	1.017	1.066	.968
Geneva, N. Y.	1	19.3	1.0824	21.41	.....	.....	2.11	.....	.....	19.30	.....	.....	.713	.....	.....
Averages, limits, and totals.	17	22.8	1.0989	25.67	29.23	19.26	2.50	3.05	1.98	23.14	26.85	16.91	.620	1.066	.503
ELVIRA.															
Kelleys Island, Ohio.	1	15.3	1.0614	15.92	.....	.....	2.35	.....	.....	13.57	.....	.....	.750	.....	.....
FRANKEN RIESLING.															
Geneva, N. Y.	1	19.5	1.0806	20.04	.....	.....	2.79	.....	.....	18.15	.....	.....	1.208	.....	.....
IONA.															
Brownhelm, Ohio.	1	19.4	1.0810	21.04	.....	.....	2.36	.....	.....	18.68	.....	.....	.660	.....	.....
Vermilion, Ohio.	1	21.5	1.0702	23.46	.....	.....	2.10	.....	.....	17.74	.....	.....	.630	.....	.....
Geneva, N. Y.	1	19.0	1.0812	21.10	.....	.....	2.10	.....	.....	19.60	.....	.....	.802	.....	.....
Averages, limits, and totals.	3	20.0	1.0841	21.87	23.46	21.04	2.07	2.36	1.74	19.80	21.72	18.68	.717	.862	.630
ISABELLA.															
Kelleys Island, Ohio.	1	18.1	1.0761	19.76	.....	.....	2.79	.....	.....	16.97	.....	.....	.645	.....	.....
IVES.															
North Bass, Ohio.	2	15.1	1.0618	16.01	16.13	15.89	2.33	2.45	2.21	13.68	13.92	13.44	.725	.826	.623
Venice, Ohio.	5	16.8	1.0694	18.02	21.04	16.28	2.61	3.23	2.15	15.34	17.52	13.74	.585	.675	.525
Vermilion, Ohio.	1	15.5	1.0628	16.28	.....	.....	2.38	.....	.....	13.90	.....	.....	.495	.....	.....
Averages, limits, and totals.	8	16.2	1.0667	17.30	21.04	15.89	2.64	3.23	2.15	14.75	17.52	13.44	.603	.826	.465
JESSICA.															
Kelleys Island, Ohio.	1	19.9	1.0851	22.12	.....	.....	2.42	.....	.....	19.70	.....	.....	.450	.....	.....

TABLE 1.—*Composition of American native grapes; average, maximum, and minimum data—Continued.*

SAMPLES FROM OHIO, NEW YORK, AND PENNSYLVANIA, 1911; EXAMINED AT SANDUSKY, OHIO; BOFF AND SHERWOOD, ANALYSTS—Contd.

Variety and locality.	Num- ber of sam- ples.	Brix.	Aver- age specific gravity.	Total solids.			Sugar-free solids.			Sugar as invert.			Acid as tartaric.		
				Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.
MISSOURI RIESLING.															
Kelleys Island, Ohio.....	1	18.7	1.0778	20.20			2.48			17.72			0.668		
Geneva, N. Y.....	1	17.5	1.0733	19.03			2.36			16.67			.803		
Averages, limits, and totals.....	2	18.1	1.0756	19.62	20.20	19.03	2.42	2.48	2.36	17.20	17.72	16.67	.736	0.803	0.668
MOLITOR.															
Middle Bass, Ohio.....	1		1.0942	24.51			4.15			20.36			1.006		
MONTEFIORE.															
Kelleys Island, Ohio.....	1		1.0911	23.70			3.40			20.30			.645		
Geneva, N. Y.....	1	15.1	1.0626	16.23			1.90			14.33			.510		
Averages, limits, and totals.....	2	15.1	1.0769	19.97	23.70	16.23	2.65	3.40	1.90	17.32	20.30	14.33	.578	.645	.510
NIAGARA.															
North Bass, Ohio.....	1	15.7	1.0651	16.88			2.61			14.27			.570		
NORTON.															
Kelleys Island, Ohio.....	1	23.2	1.0998	25.99			3.93			22.06			1.642		
Sandusky, Ohio.....	2	22.7	1.0978	25.45	25.72	25.17	3.46	3.46	3.45	21.99	22.26	21.72	1.037	1.065	.998
Venice, Ohio.....	1	24.2	1.1062	27.67			3.50			23.17			1.343		
Geneva, N. Y.....	1	22.5	1.0928	24.14			3.93			20.21			2.212		
Averages, limits, and totals.....	5	23.1	1.0989	25.94	27.67	24.14	3.66	4.50	3.45	21.88	23.17	20.21	1.452	2.212	.998
SCHRAUDT.															
North Bass, Ohio.....	3	20.7	1.0875	22.74	23.38	22.28	3.90	4.19	3.49	18.85	19.37	18.09	1.600	1.672	1.545
SEIBEL NO. 2.															
Geneva, N. Y.....	1	13.6	1.0553	14.33			3.23			11.10			1.852		

TRIUMPH.	
Geneva, N. Y.	1
	12.7
	1.0514
	13.31
	2.22
	11.09
	1.012
	12.77
	13.46
	2.28
	1.952
	.892
WOEDEN.	
Fredonia, N. Y.	2
	14.5
	1.0589
	15.27
	14.98
	2.31
	2.34

SAMPLES FROM CHARLOTTESVILLE, VA., 1911; HARTMANN, ANALYST.

CONCORD.	
Charlottesville, Va.	3
	1.0792
	20.58
	21.48
	19.40
	2.47
	3.14
	2.04
	18.11
	18.62
	17.36
	0.530
	0.533
	0.525
CYNTHIANA.	
Charlottesville, Va.	2
	22.6
	1.0955
	24.95
	24.96
	24.93
	2.72
	4.16
	3.27
	21.23
	21.66
	20.80
	.767
	.780
	.754
DELAWARE.	
Charlottesville, Va.	1
	25.1
	1.1084
	28.24
	2.44
	25.80
	.645
IVES.	
Charlottesville, Va.	1
	18.0
	1.0751
	19.50
	3.60
	15.90
	.750
NIAGARA.	
Charlottesville, Va.	1
	14.6
	1.0610
	15.82
	2.26
	13.14
	.810
NOAIL.	
Charlottesville, Va.	1
	21.0
	1.0883
	22.96
	2.71
	20.25
	7.50
NORTON.	
Charlottesville, Va.	7
	22.8
	1.0968
	25.23
	26.59
	23.46
	3.74
	3.94
	3.64
	22.90
	19.82
	.867
	.990
	.743
UNKNOWN.	
Charlottesville, Va.	2
	20.3
	1.0840
	21.82
	22.52
	21.12
	2.26
	2.42
	2.10
	19.56
	20.42
	18.70
	.735
	.735

TABLE 1.—*Composition of American native grapes; average, maximum, and minimum data—Continued.*

SAMPLES FROM NEW JERSEY, 1913; ALWOOD, CARRERO, AND HARDING, ANALYSTS.

Variety and locality.	Num- ber of speci- fic sam- ples.	Brix.	Aver- age specific gravity.	Total solids.			Sugar-free solids.			Sugar as invert.			Acid as tartaric.		
				Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.
BRILLIANT.															
Vineland, N. J.	1		1.0882	22.93			4.22			18.71			0.676		
CANADA.															
Vineland, N. J.	1		1.0705	18.30			3.70			14.60			1.028		
CAMPBELL'S EARLY.															
Vineland, N. J.	1		1.0721	18.71			3.81			14.90			.540		
CATAWBA.															
Vineland, N. J.	1		1.0767	19.92			3.69			16.23			1.042		
CLEVERER.															
Egg Harbor, N. J.	1		1.0617	16.00			3.94			12.06			1.425		
Germania, N. J.	1		1.0700	16.16			4.78			13.38			1.328		
Vineland, N. J.	1		1.0766	19.89			4.20			15.69			1.102		
Averages, limits, and totals.	3		1.0694	18.02	19.89	16.00	4.31	4.78	3.94	13.68	15.69	12.06	1.285	1.425	1.102
CLINTON.															
Egg Harbor, N. J.	1		1.0770	20.00			3.44			16.56			1.729		
Germania, N. J.	1		1.0909	23.65			3.38			20.27			1.646		
Vineland, N. J.	1		1.0810	21.04			3.95			17.09			1.800		
Averages, limits, and totals.	3		1.0830	21.53	23.65	20.00	3.59	3.95	3.38	17.94	20.27	16.56	1.732	1.800	1.646
CONCORD.															
Egg Harbor, N. J.	1		1.0617	16.00			1.68			14.32			.619		
Germania, N. J.	1		1.0772	17.43			3.40			14.03			.758		
Vineland, N. J.	1		1.0682	17.69			3.80			13.89			.818		
Averages, limits, and totals.	3		1.0657	17.04	17.69	16.00	2.96	3.80	1.68	14.08	14.32	13.89	.732	.818	.619

CONQUEROR.													
	1	1	1.0634 1.0632	16.44 16.39				3.82 3.16			12.62 13.23		1.132 1.016
	2		1.0633	16.42	16.44	16.39		3.49	3.82	3.16	12.98	13.23	1.074 1.132
Averages, limits, and totals.....													
CYNTHIANA.													
	1		1.0870 1.0998	22.62 25.99				4.88 5.35			17.74 20.64		1.350 1.182
	2		1.0934	24.31	25.99	22.62		5.12	5.35	4.88	19.24	20.64	1.266 1.350
Averages, limits, and totals.....													
DELAWARE.													
	1		1.1023	26.64				4.25			22.39		.660
DIOGENES.													
	2		1.0757 1.0651	19.66 16.88	20.70	18.61		4.46 4.38	5.23	3.69	15.20 12.30	15.47	1.548 1.702
	3		1.0722	18.73	20.70	16.88		4.50	5.23	3.69	14.23	15.47	1.599 1.702
Averages, limits, and totals.....													
DUTCHESS.													
	1		1.0804	20.89				4.11			16.78		.586
EUMELAN.													
	1		1.0865	22.49				4.11			18.38		.706
FRANKLIN.													
	1		1.0914	23.77				5.36			18.41		1.188
GOETHE.													
	1		1.0691	17.93				2.81			15.12		.888
HERBEMONT.													
	1		1.0735	19.08				3.53			15.55		.904
IVES.													
	3		1.0631 1.0661 1.0633 1.0713	16.35 17.14 16.40 18.50	16.91	15.79		2.76 3.88 2.96 4.09	3.25	2.27	13.52 13.26 14.47 14.42	14.64	.724 .706 .870 .578
	4				17.22	15.48		3.17			12.49	14.47	.930
	4				20.26	16.10		4.37			12.82	16.07	.680
Averages, limits, and totals.....													
	12		1.0664	21.22	20.26	15.48		3.41	4.37	2.27	13.77	16.07	.723 .930
Averages, limits, and totals.....													

12 samples analyzed.

TABLE 1. *Composition of American native grapes; average, maximum, and minimum data—Continued.*
 SAMPLES FROM NEW JERSEY, 1913; ALWOOD, CARRERO, AND HARDING, ANALYSTS—Continued.

Variety and locality.	Num- ber of sam- ples.	Brix.	Aver- age specific gravity.	Total solids.			Sugar-free solids.			Sugar as invert.			Acid as tartaric.		
				Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.
JEFFERSON.															
Vineland, N. J.	1		1.0816	21.20			3.75			17.45			0.886		
LENOIR.															
Vineland, N. J.	1		1.0730	18.95			4.05			14.90			1.546		
LINDLEY.															
Vineland, N. J.	1		1.0766	19.89			2.97			16.92			.704		
MOORE DIAMOND.															
Egg Harbor, N. J.	1		1.0779	20.23			2.75			17.48			.634		
NOAH.															
Egg Harbor, N. J.	1		1.0658	17.07			4.20			12.87			1.372		
Vineland, N. J.	2		1.0841	21.85	22.88	20.81	3.59	3.93	3.25	18.26	18.95	17.56	.962	1.084	0.840
Averages, limits, and totals.	3		1.0780	20.25	22.88	17.07	3.79	4.20	3.25	16.46	18.95	12.87	1.099	1.372	.840
NORTON.															
Egg Harbor, N. J.	2		1.0816	21.19	22.17	20.20	4.91	5.39	4.43	16.28	17.74	14.81	1.483	1.598	1.368
Vineland, N. J.	1		1.0937	24.38			3.94			20.44			1.204		
Averages, limits, and totals.	3		1.0876	22.25	24.38	20.20	4.59	5.39	3.91	17.67	20.44	14.81	1.390	1.598	1.204
MISSOURI RIESLING.															
Vineland, N. J.	1		1.0805	20.91			3.61			17.30			.886		
SALEM.															
Vineland, N. J.	1		1.0846	21.99			4.58			17.41			1.085		
TAYLOR.															
Egg Harbor, N. J.	1		1.0855	22.22			3.14			19.08			1.106		
Germania, N. J.	1		1.0790	20.52			4.46			16.06			1.546		
Averages, limits, and totals.	2		1.0823	21.37	22.22	20.52	3.80	4.46	3.14	17.57	19.08	16.06	1.376	1.546	1.106

SAMPLES FROM KEUKA DISTRICT, 1913; ALWOOD AND HARDING, ANALYSTS.

ULSTER.		1	1.0885	23.01	3.78	19.23	.684	
Vineland, N. J.		1						
WINCHELL.								
Egg Harbor, N. J.		1	1.0855	22.22	2.94	19.28	.506	
WOODRUFF.								
Vineland, N. J.		1	1.0709	18.40	4.86	13.54	.660	
AGAWAM.								
Hammondsport, N. Y.		1	1.0775	20.12				
Putney, N. Y.		2	1.0859	22.33				
Urbana, N. Y.		1	1.0846	21.99	1.92	18.20	0.856	
Averages, limits, and totals.		4			3.14	19.48	1.016	0.952
					2.51	19.48	.528	
CATAWBA.								
Dundee, N. Y.		2	1.0801	23.17	3.41	19.76	1.320	1.312
Grove Springs, N. Y.		1	1.0923	24.01	3.61	20.40	1.200	
Hammondsport, N. Y.		14	1.0737	19.13	2.79	18.36	1.247	.862
Naples, N. Y.		2	1.0737	19.13	2.92	16.21	1.523	1.260
Penn Yan, N. Y.		5	1.0808	22.37	3.01	19.56	1.200	
Putney, N. Y.		5	1.0838	22.24	3.24	20.18	1.284	1.156
Averages, limits, and totals.		25	1.0833	21.65	2.98	18.67	1.270	.862
					3.79	21.84	1.786	
CONCORD.								
Dundee, N. Y.		2	1.0848	22.04	2.49	19.55	.708	.704
Hammondsport, N. Y.		20	1.0754	19.58	5.47	20.26	.833	.600
Keuka, N. Y.		1	1.0837	21.75	2.61	19.14	1.456	
Naples, N. Y.		2	1.0729	18.91	2.55	17.34	.584	.758
Penn Yan, N. Y.		1	1.0891	23.17	2.29	20.88	.458	
Putney, N. Y.		2	1.0737	19.13	2.33	17.02	.722	.604
Averages, limits, and totals.		28	1.0766	19.88	2.72	17.16	.804	.488
					5.47	20.80	1.456	
CLINTON.								
Hammondsport, N. Y.		11	1.0983	24.58	1.407	21.43	1.858	.930
Naples, N. Y.		1	1.0864	22.46	4.12	18.34	2.558	
Putney, N. Y.		1	1.0570	21.47	3.25	11.52	2.250	
Averages, limits, and totals.		13	1.0938	23.58	3.401	20.43	1.942	.930
					4.52	23.48	2.558	

1 Only 10 determinations made.

2 Foliage destroyed.

3 Average of 12 determinations.

TABLE 1.—*Composition of American native grapes; average, maximum, and minimum data—Continued.*
 SAMPLES FROM KEUKA DISTRICT, 1913; ALWOOD AND HARDING, ANALYSTS—Continued.

Variety and locality.	Num- ber of sam- ples.	Brix.	Aver- age specific gravity.	Total solids.			Sugar-free solids.			Sugar as invert.			Acid as tartaric.		
				Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.
WHITE CLINTON.															
Hammondsport, N. Y.	1	.....	1.0986	25.67	.....	.....	3.89	.....	.....	21.78	.....	.....	1.298	.....	.....
DELAWARE.															
Hammondsport, N. Y.	3	.....	1.0944	24.52	25.43	23.04	2.78	2.90	2.68	21.78	22.68	20.14	.958	1.028	0.856
Naples, N. Y.	1	.....	1.0973	25.33	.....	.....	2.69	.....	.....	22.64	.....	.....	.728	.....	.....
Urbana, N. Y.	1	.....	1.0982	25.56	.....	.....	3.10	.....	.....	22.46	.....	.....	.952	.....	.....
.....	1	.....	1.0927	24.12	.....	.....	2.56	.....	.....	21.56	.....	.....	1.102	.....	.....
Averages, limits, and totals.	6	.....	1.0952	24.76	25.56	23.04	2.78	3.10	2.56	22.00	22.68	20.14	.943	1.102	.728
DIANA.															
Hammondsport, N. Y.	5	.....	1.0851	22.39	23.41	20.57	3.78	4.28	3.27	18.61	19.60	17.30	.994	1.118	.922
Pulteney, N. Y.	1	.....	1.0855	22.22	.....	.....	2.46	.....	.....	19.76	.....	.....	.946	.....	.....
Averages, limits, and totals.	6	.....	1.0860	22.36	23.41	20.57	3.56	4.28	2.46	18.80	19.76	17.30	.986	1.118	.922
DUTCHESS.															
Naples, N. Y.	1	.....	1.0766	19.89	.....	.....	1.87	.....	.....	18.02	.....	.....	.704	.....	.....
ELVIRA.															
Urbana, N. Y.	4	.....	1.0634	17.09	18.78	15.79	2.86	3.35	2.60	14.16	15.12	13.19	1.288	1.402	1.230
TONA.															
Hammondsport, N. Y.	3	.....	1.0841	21.87	22.80	20.81	3.02	3.85	2.41	18.87	20.06	16.96	1.238	1.426	1.118
ISABELLA.															
Dundee, N. Y.	1	.....	1.0828	21.52	.....	.....	3.18	.....	.....	18.34	.....	.....	1.012	.....	.....
Hammondsport, N. Y.	6	.....	1.0725	18.82	21.86	16.23	2.45	2.93	1.99	16.38	19.34	14.15	1.247	1.658	.960
Naples, N. Y.	2	.....	1.0564	14.60	15.89	13.31	2.29	2.47	2.11	12.31	13.78	10.84	1.282	1.432	1.132
Averages, limits, and totals.	9	.....	1.0701	18.16	21.86	13.31	2.49	3.18	1.99	15.69	19.34	10.84	1.228	1.658	.960

TABLE 2.—*Composition of muscadine grapes grown in North Carolina, 1913; Atwood and Carver, analysts.*

[Results stated in grams per 100 cc of expressed juice.]

Variety and locality.	Num- ber of sam- ples.	Aver- age spe- cific grav- ity.	Total solids.			Sugar-free solids.			Sugar as reducing.			Sucrose.			Total sugar as invert.			Acid as tartaric.		
			Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.	Aver- age.	Maxi- mum.	Mini- mum.
EDEN.																				
Willard, N. C.	3	1.0506	13.10	14.93	10.82	2.02	2.58	1.09	11.08	13.24	8.24				1.137	1.678	0.818			
FLOWERS.																				
Willard, N. C.	2	1.0445	11.51	12.25	10.76	2.36	2.59	2.12	9.15	10.13	8.17				1.264	1.388	1.140			
JAMES.																				
Willard, N. C.	3	1.0492	12.73	14.74	11.49	1.98	3.07	1.30	10.75	13.18	8.42				.691	.908	.534			
LUOLA.																				
Willard, N. C.	1	1.0536	13.89			1.41			12.48						.630					
MISH.																				
Enfield, N. C.	1	1.0579	15.00			4.28			10.71						.624					
Fayetteville, N. C.	1	1.0513	13.29			4.23			9.06						.736					
Averages, limits, and totals	2	1.0546	14.15	15.00	13.29	4.26	4.29	4.23	9.89	10.71	9.06				.680	.736	.624			
SCUPERNONG.																				
Chinquapin, N. C.	4	1.0558	14.47	14.45	13.49	1.66	1.70	1.60	11.44	12.27	10.60	1.37	1.64	1.13	12.88	13.85	11.86	.698	.772	.578
Jacksonville, N. C.	3	1.0508	13.16	14.43	11.70	1.18	1.61	.71	10.71	11.80	9.62	1.27	1.95	.47	12.04	13.26	10.11	.713	.766	.660
Willard, N. C.	3	1.0569	14.75	16.07	13.89	1.91	2.79	1.27	12.10	13.37	11.10	1.12	1.21	1.03	13.76	14.45	13.06	.863	.952	.818
Averages, limits, and totals.	10	1.0547	14.16	16.07	11.70	1.59	2.79	.71	11.42	13.37	9.62	1.28	1.95	.47	12.80	14.45	10.11	.752	.952	.579
SMITH.																				
Willard, N. C.	2	1.0552	14.29	14.77	13.81	1.61	1.81	1.20	12.69	13.37	12.00				.839	.906	.772			
THOMAS.																				
Willard, N. C.	2	1.0598	15.49	16.10	14.87	4.94	5.31	4.56	10.55	11.54	9.56				.800	.833	.766			

¹ Two samples analyzed.² Nine samples analyzed.

DISCUSSION OF ANALYTICAL RESULTS.

1911 SAMPLES.

The remarkably high quality of the samples of the standard varieties collected in 1911, examined at Sandusky and Charlottesville, is worthy of emphasis, because of the statement so frequently made in the past that our native grapes are unfit for wines or other by-products without a large addition of sugar or sugar solution. It may be noted that 28 samples of Catawba from the northern Ohio district average 20.24 grams of sugar and 0.709 gram of acid in 100 cc, or an acid-sugar ratio of 1 to 28.6. Such fruit properly handled does not require any amelioration for unfermented juice or for wine. In this connection it is important to note that this is the lowest acid content found for Catawba but not the highest sugar content. The crop of 1911 was exceptionally well balanced as to the ratio of acid and sugar content in most varieties.

Clinton for five samples examined shows 21.62 grams of sugar and 1.173 grams of acid in 100 cc, or an acid-sugar ratio of 1 to 18.4. This is the highest sugar content recorded for Clinton, and also the widest acid-sugar ratio.

The Concord samples show remarkable acid-sugar ratios. For both northern Ohio and Virginia samples this is about 1 to 34, and 23 Concord samples collected from other northern points outside of Ohio show an acid-sugar ratio of 1 to 25.9.

Cynthiana and Norton are similar varieties in appearance, growth, and general character of fruit but show differences in composition which are quite important. Cynthiana in Virginia gives 21.23 grams of sugar and 0.767 gram of acid in 100 cc, or an acid-sugar ratio of 1 to 27.7, while Norton, with 21.49 grams of sugar and 0.867 gram of acid in 100 cc of juice, shows an acid-sugar ratio of 1 to 24.8. From the well-known character of the juice of these grapes, and the large precipitation of cream of tartar which will occur with correct treatment, the acid content is rather low for producing a pleasant, sprightly food product.

1913 SAMPLES.

The samples collected in North Carolina were of varieties of the *Vitis rotundifolia* species commonly called muscadine grapes. Since these are grown quite extensively for the manufacture of wine, it was desirable to obtain information as to their composition. Their acid content is in most cases favorable to wine making. Ten samples were examined for sucrose with the result that this form of sugar was found in appreciable quantity. The results here given are on the expressed juice.

The New Jersey samples introduce a few names not heretofore recorded in this work. None of the samples from this district show a high sugar content; in fact they are mostly low in sugar when

compared with other districts. Such little-grown varieties as Clevener and Diogenes give a juice of very deep color and are desired for blending in making red wines. The grape-growing districts of New Jersey need further attention before it will be possible to draw conclusions of value on the quality of the crop.

SUMMARY OF DATA ON SUGAR AND ACID FOR FIVE YEARS.

Table 3 brings together the results for sugar and acid determinations of all the varieties, with a few exceptions, examined during the five years' work, 1908, 1909, 1910, 1911, and 1913. The exceptions are the muscadine varieties and a number of unnamed and undisseminated seedlings. When more than one sample was analyzed the average is given. The data from which this table is compiled are the same as given in the tables of Bureau of Chemistry Bulletin 145, pages 20 to 35, and in Table 1 of this bulletin. So far as possible the results are grouped by districts for those kinds of grapes of which a considerable number of samples have been examined from several districts. The following groups are used: "Northern Ohio" includes the vineyards along the shore of Lake Erie and the islands off Sandusky; "New York" includes the Geneva, Keuka, and Chautauqua districts; other northern districts, from which samples did not distinctly represent any one district, are given as "Other Northern," and if for the reason that only a few widely-scattered samples of a variety were collected no division is made into districts the samples are given as from "All Northern." Southern samples were taken from restricted areas and are so grouped.

The summary presented in Table 3 covering the five-year period shows some interesting comparisons on samples which were taken with care and in sufficient number to warrant the belief that they represent the facts. For instance, Catawba for northern Ohio, one of the rather strongly-acid fruits, shows a very narrow range of average sugar for the several years, from 18.05 grams to 20.78 grams in 100 cc of juice during four years, but with a variation of acid from 0.709 gram to 1.155 grams in 100 cc or in acid-sugar ratios a variation from 1 to 15.6 to 1 to 28.6.

Take also the example of Concord, one of the varieties of medium content of sugar and moderately low in acid. Here again the range in sugar content is slight, being from 15.74 grams to 18.51 grams in 100 cc with an acid range from 0.466 gram to 0.757 gram in 100 cc. This gives acid-sugar ratios running from 1 to 22.4 to 1 to 37.3.

Delaware shows the most phenomenal acid-sugar ratio of any variety examined. Comparing only the northern Ohio samples for 1909, 1910, and 1911, because these are the more representative, the ratios extend from 1 to 26.0 to 1 to 43.8. Certainly the latter ratio is entirely too wide for a properly balanced grape juice or for a dry wine. Such low acidity endangers the keeping quality of the products.

A high or low acid-sugar ratio itself carries no index of richness or food quality. It is simply a statement of the balance between these elements compared with each other and indicates agreeableness or lack of agreeableness to the palate. A rich juice may be quite acid in its fresh state, as for instance, Norton for northern Ohio, 1911, which is indeed a rich juice but with an acid-sugar ratio of 1 to 17.8, entirely too narrow for a potable juice in the fresh state. The indications are that the amelioration of such a juice by proper factory technic is possible.

TABLE 3.—*Comparison of total sugar and acid results for all named varieties analyzed during 1908–1911 and 1913, with acid-sugar ratios.*

[Results stated in grams per 100 cc of expressed juice.]

Variety.	Year.	District.	Number of samples.	Sugar as invert.	Acid as tartaric.	Acid-sugar ratio.
Adirondac.....	1910	All northern.....	1	10.19	0.911	1:11.2
Agawam.....	1909	do.....	2	17.90	.840	1:21.3
Do.....	1910	New York.....	3	15.28	1.344	1:11.4
Do.....	1913	do.....	4	19.02	.854	1:22.3
Amber Queen.....	1910	do.....	1	16.02	1.436	1:11.2
America.....	1910	do.....	1	16.94	1.436	1:11.8
Aminia.....	1910	do.....	1	16.68	.821	1:20.3
Bacchus.....	1908	Northern Ohio.....	2	20.51	1.205	1:17.0
Do.....	1909	All northern.....	7	19.64	1.852	1:10.6
Do.....	1910	Northern Ohio.....	2	17.42	1.770	1: 9.8
Do.....	1911	All northern.....	3	18.34	1.347	1:13.6
Barry.....	1910	New York.....	1	12.12	1.159	1:10.5
Belle.....	1910	do.....	1	18.78	1.114	1:16.9
Big Extra.....	1910	do.....	1	13.91	1.466	1: 9.5
Black Eagle.....	1910	do.....	2	17.57	1.011	1:17.4
Brighton.....	1909	Northern Ohio.....	2	20.47	.632	1:32.4
Do.....	1910	All northern.....	7	18.67	.822	1:21.2
Brilliant.....	1913	New Jersey.....	1	18.71	.676	1:27.7
Brown.....	1910	New York.....	1	13.64	1.106	1:12.3
Butler No. 1.....	1910	do.....	1	17.03	.833	1:20.4
Campbell Early.....	1909	Northern Ohio.....	1	13.61	.784	1:17.4
Do.....	1910	All northern.....	4	15.56	.884	1:17.9
Do.....	1913	New Jersey.....	1	14.90	.540	1:27.6
Canada.....	1913	do.....	1	14.60	1.028	1:14.2
Carman.....	1910	New York.....	1	13.29	1.654	1: 8.0
Catawba.....	1908	Northern Ohio.....	25	20.45	.775	1:26.4
Do.....	1909	do.....	84	18.05	1.155	1:15.6
Do.....	1909	Other northern.....	7	16.22	¹ 1.552	1:10.4
Do.....	1910	Northern Ohio.....	84	20.78	1.071	1:19.4
Do.....	1910	Other northern.....	9	18.76	1.431	1:13.1
Do.....	1911	Northern Ohio.....	28	20.24	.709	1:28.6
Do.....	1911	Other northern.....	1	17.64	.892	1:19.8
Do.....	1913	New York.....	25	18.67	1.270	1:14.7
Do.....	1913	New Jersey.....	1	16.23	1.042	1:15.6
Champion.....	1910	New York.....	1	11.90	.915	1:13.0
Chautauqua.....	1910	do.....	1	13.50	1.043	1:12.9
Clevener.....	1910	do.....	1	14.96	1.196	1:12.5
Do.....	1913	New Jersey.....	3	13.68	1.285	1:10.6
Clinton.....	1908	Northern Ohio.....	5	19.28	1.081	1:17.8
Do.....	1909	do.....	13	17.73	1.686	1:10.5
Do.....	1909	Other northern.....	4	18.69	2.061	1: 9.1
Do.....	1910	Northern Ohio.....	3	20.80	1.918	1:10.8
Do.....	1910	Other northern.....	4	19.03	2.130	1: 8.9
Do.....	1911	Northern Ohio.....	5	21.62	1.173	1:18.4
Do.....	1913	New York.....	13	20.43	1.942	1:10.5
Do.....	1913	New Jersey.....	3	17.94	1.732	1:10.4
Cloeta.....	1910	New York.....	1	16.02	1.088	1:14.7
Colerain.....	1910	do.....	1	12.76	.870	1:14.7
Concord.....	1908	Northern Ohio.....	11	17.40	.466	1:37.3
Do.....	1909	do.....	46	15.74	² .702	1:22.4
Do.....	1909	Other northern.....	30	15.92	³ .804	1:19.8
Do.....	1909	Virginia.....	14	16.01	.744	1:21.5
Do.....	1910	Northern Ohio.....	30	18.51	.757	1:24.4

¹ Acid average of 6 samples.

² Acid average of 41 samples.

³ Acid average of 29 samples.

TABLE 3.—Comparison of total sugar and acid results for all named varieties analyzed during 1908–1911 and 1913, with acid-sugar ratios—Continued.

Variety.	Year.	District.	Number of samples.	Sugar as invert.	Acid as tartaric.	Acid-sugar ratio.
Concord.....	1910	Other northern....	58	16.45	0.888	1:18.5
Do.....	1910	Virginia.....	12	16.33	.823	1:19.8
Do.....	1911	Northern Ohio.....	11	17.87	.525	1:34.0
Do.....	1911	Other northern.....	23	16.93	.654	1:25.9
Do.....	1911	Virginia.....	3	18.11	.530	1:34.2
Do.....	1913	New York.....	62	17.49	.747	1:23.4
Do.....	1913	New Jersey.....	3	14.08	.732	1:19.2
Conqueror.....	1913	do.....	2	12.98	1.074	1:12.1
Corby.....	1910	New York.....	1	13.77	.938	1:14.7
Creveling.....	1910	do.....	1	13.93	1.009	1:13.8
Croton.....	1910	do.....	1	11.84	.788	1:15.0
Cynthiana.....	1909	Northern Ohio.....	1	19.10	1.598	1:12.0
Do.....	1909	Virginia.....	1	19.75	.986	1:20.0
Do.....	1910	do.....	1	21.10	1.080	1:19.5
Do.....	1911	do.....	2	21.23	.767	1:27.7
Do.....	1913	New Jersey.....	2	19.24	1.266	1:15.2
Daisy.....	1910	New York.....	1	16.95	.653	1:26.0
Delago.....	1910	do.....	1	17.25	1.009	1:17.1
Delaware.....	1908	Northern Ohio.....	2	25.24	.467	1:54.1
Do.....	1909	do.....	22	21.08	1.809	1:26.0
Do.....	1909	Other northern.....	14	19.86	.853	1:22.9
Do.....	1909	Virginia.....	2	22.45	.702	1:32.0
Do.....	1910	Northern Ohio.....	11	24.09	.794	1:30.3
Do.....	1910	Other northern.....	18	19.70	1.001	1:19.7
Do.....	1910	Virginia.....	1	21.00	.551	1:38.1
Do.....	1911	Northern Ohio.....	14	24.37	.556	1:43.8
Do.....	1911	New York.....	3	18.06	.916	1:19.7
Do.....	1911	Virginia.....	1	25.80	.645	1:40.0
Do.....	1913	New York.....	6	22.00	.943	1:23.3
Do.....	1913	New Jersey.....	1	22.39	.660	1:33.9
Diamond.....	1910	New York.....	2	16.52	1.053	1:15.6
Do.....	1913	New Jersey.....	1	17.48	.634	1:24.4
Diana.....	1909	Northern Ohio.....	1	19.90	.950	1:20.7
Do.....	1910	All northern.....	4	20.27	.965	1:21.0
Do.....	1913	New York.....	6	18.80	.986	1:19.1
Diogenes.....	1913	New Jersey.....	3	14.23	1.599	1: 8.9
Dutchess.....	1910	New York.....	3	17.48	.734	1:23.8
Do.....	1913	do.....	1	18.02	.704	1:25.6
Do.....	1913	New Jersey.....	1	16.78	.586	1:28.6
Early Dawn.....	1910	New York.....	1	16.22	1.065	1:15.2
Early Golden.....	1910	do.....	1	18.50	.848	1:21.8
Eldorado.....	1910	do.....	1	19.63	.784	1:25.0
Elvira.....	1909	Northern Ohio.....	8	14.29	1.002	1:14.3
Do.....	1909	Virginia.....	1	15.35	.735	1:20.9
Do.....	1910	Northern Ohio.....	4	17.16	.913	1:18.8
Do.....	1910	New York.....	4	14.23	1.253	1:11.4
Do.....	1911	Northern Ohio.....	1	13.57	.750	1:18.1
Do.....	1913	New York.....	4	14.16	1.288	1:11.0
Empire State.....	1910	All northern.....	2	16.10	.704	1:22.9
Etta.....	1909	Northern Ohio.....	1	11.24	1.369	1: 8.2
Eumelan.....	1910	do.....	1	13.54	.930	1:14.6
Do.....	1910	New York.....	4	17.80	.961	1:18.5
Do.....	1913	New Jersey.....	1	18.38	.706	1:26.0
Franken Riesling.....	1911	New York.....	1	18.15	1.208	1:15.0
Franklin.....	1913	New Jersey.....	1	18.41	1.188	1:15.5
Goethe.....	1913	do.....	1	15.12	.888	1:17.0
Goff.....	1910	New York.....	2	15.64	.895	1:17.5
Gold Dust.....	1910	do.....	1	15.71	.694	1:22.6
Golden.....	1910	do.....	1	17.04	.420	1:40.6
Glenfeld.....	1910	do.....	1	14.56	1.106	1:13.2
Green Early.....	1909	Northern Ohio.....	1	14.21	.758	1:18.8
Gut Edel.....	1909	do.....	1	20.20	1.144	1:17.7
Do.....	1910	do.....	1	20.36	1.350	1:15.1
Hayes.....	1909	do.....	1	18.45	.893	1:20.7
Do.....	1910	do.....	1	15.16	1.118	1:13.6
Hartford.....	1910	New York.....	2	15.81	.893	1:17.7
Herbert.....	1910	do.....	1	16.54	1.200	1:13.8
Herbmont.....	1913	New Jersey.....	1	15.55	.904	1:17.2
Hexamer.....	1910	New York.....	1	16.36	1.245	1:13.1
Hicks.....	1910	do.....	1	13.32	1.159	1:11.5
Honey Dew.....	1910	do.....	1	16.34	.956	1:17.1
Illinois City.....	1910	do.....	1	17.81	.998	1:17.8
Iona.....	1908	Northern Ohio.....	1	21.09	.679	1:31.1
Do.....	1909	All northern.....	4	19.78	.836	1:23.7
Do.....	1910	Northern Ohio.....	5	21.31	.866	1:24.6

¹ Acid average of 17 samples.

TABLE 3.—Comparison of total sugar and acid results for all named varieties analyzed during 1908-1911 and 1913, with acid-sugar ratios—Continued.

Variety.	Year.	District.	Number of samples.	Sugar as invert.	Acid as tartaric.	Acid-sugar ratio.
Iona.....	1910	New York.....	3	20.23	1.235	1:16.4
Do.....	1911	All northern.....	3	19.80	.717	1:27.6
Do.....	1913	New York.....	3	18.87	1.238	1:15.2
Isabella.....	1908	Northern Ohio.....	2	19.89	.540	1:36.8
Do.....	1909	All northern.....	6	13.91	1.008	1:13.8
Do.....	1910	do.....	9	16.75	.957	1:17.5
Do.....	1911	Northern Ohio.....	1	16.97	.645	1:26.3
Do.....	1913	New York.....	9	15.69	1.228	1:15.4
Ives.....	1908	Northern Ohio.....	19	16.12	.519	1:31.1
Do.....	1909	do.....	28	15.03	1.766	1:19.6
Do.....	1909	Other northern.....	3	11.80	.788	1:15.0
Do.....	1909	Virginia.....	12	15.11	.753	1:20.1
Do.....	1910	Northern Ohio.....	18	16.84	.743	1:21.3
Do.....	1910	Other northern.....	4	16.03	.917	1:17.5
Do.....	1910	Virginia.....	15	15.38	.714	1:21.5
Do.....	1911	Northern Ohio.....	8	14.75	.609	1:24.3
Do.....	1911	Virginia.....	1	15.90	.750	1:21.2
Do.....	1913	New York.....	3	14.37	.843	1:15.9
Do.....	1913	New Jersey.....	12	13.77	.723	1:19.1
Janesville.....	1910	New York.....	1	13.95	1.462	1: 9.6
Jefferson.....	1913	New Jersey.....	1	17.45	.886	1:19.7
Jessica.....	1911	Northern Ohio.....	1	19.70	.450	1:43.8
Lenoir.....	1913	New Jersey.....	1	14.90	1.546	1: 9.6
Lindley.....	1910	New York.....	2	15.61	1.054	1:14.8
Do.....	1913	do.....	1	18.54	.720	1:25.8
Do.....	1913	New Jersey.....	1	16.92	.704	1:24.0
Lucile.....	1910	New York.....	2	14.46	.865	1:16.7
Marion.....	1909	Northern Ohio.....	1	20.77	1.718	1:12.1
Do.....	1910	New York.....	2	17.31	1.566	1:11.1
Martha.....	1909	do.....	1	16.07	.840	1:19.1
Massasoit.....	1910	do.....	1	15.21	.754	1:20.2
Maxfield.....	1913	do.....	1	15.87	.796	1:19.9
Mills.....	1910	do.....	2	19.85	.741	1:26.9
Missouri Riesling.....	1908	Northern Ohio.....	1	18.57	.656	1:28.3
Do.....	1909	do.....	3	19.13	.894	1:21.4
Do.....	1909	Virginia.....	1	14.30	.851	1:16.8
Do.....	1910	Northern Ohio.....	1	18.36	.941	1:19.5
Do.....	1911	do.....	2	17.20	.736	1:23.4
Do.....	1913	New Jersey.....	1	17.30	.886	1:19.5
Molitor.....	1911	Northern Ohio.....	1	20.36	1.006	1:20.2
Montefiore.....	1908	do.....	1	24.80	.401	1:61.8
Do.....	1909	do.....	4	19.96	.842	1:23.7
Do.....	1910	do.....	1	21.36	.784	1:27.2
Do.....	1911	All northern.....	2	17.32	.578	1:30.0
Moore Diamond.....	1913	New Jersey.....	1	17.48	.634	1:24.4
Moore Early.....	1910	New York.....	1	9.04	.825	1:11.0
Moyer.....	1910	do.....	2	17.61	.711	1:24.8
Munson.....	1910	do.....	1	13.57	1.490	1: 9.1
Nectar.....	1910	do.....	1	17.26	1.256	1:13.7
Niagara.....	1909	Northern Ohio.....	6	14.85	.615	1:24.1
Do.....	1909	Other northern.....	10	16.34	2.683	1:23.9
Do.....	1910	Northern Ohio.....	2	18.92	.448	1:42.2
Do.....	1910	Other northern.....	6	13.87	.822	1:16.9
Do.....	1911	Northern Ohio.....	1	14.27	.570	1:25.0
Do.....	1911	Virginia.....	1	13.14	.810	1:16.2
Do.....	1913	New York.....	6	15.96	.617	1:25.9
Noah.....	1909	Virginia.....	2	20.06	.957	1:21.0
Do.....	1910	New York.....	1	14.25	1.632	1: 8.7
Do.....	1911	Virginia.....	1	20.25	.750	1:27.0
Do.....	1913	New Jersey.....	3	16.46	1.099	1:14.9
Norton.....	1908	Northern Ohio.....	3	25.27	1.006	1:25.1
Do.....	1908	Virginia.....	9	22.63	1.088	1:20.8
Do.....	1909	Northern Ohio.....	11	19.50	1.812	1:10.8
Do.....	1909	Virginia.....	11	21.35	.925	1:23.1
Do.....	1910	Northern Ohio.....	5	21.41	1.683	1:12.7
Do.....	1910	Virginia.....	23	22.44	.957	1:23.4
Do.....	1911	Northern Ohio.....	4	22.30	1.262	1:17.8
Do.....	1911	New York.....	1	20.21	2.212	1: 9.1
Do.....	1911	Virginia.....	7	21.49	.867	1:24.8
Do.....	1913	New Jersey.....	3	17.67	1.390	1:12.7
Norfolk.....	1910	New York.....	1	16.10	1.144	1:14.1
Olita.....	1910	do.....	1	15.97	.908	1:17.6
Pierce.....	1910	do.....	1	12.42	1.253	1: 9.9
Pocklington.....	1909	All northern.....	3	16.85	.700	1:24.1
Do.....	1910	Northern Ohio.....	2	17.04	.846	1:20.1

¹ Acid average of 26 samples.² Acid average of 9 samples.

TABLE 3.—*Comparison of total sugar and acid results for all named varieties analyzed during 1908-1911 and 1913, with acid-sugar ratios—Continued.*

Variety.	Year.	District.	Number of samples.	Sugar as invert.	Acid as tartaric.	Acid-sugar ratio.
Prentiss.....	1913	New York.....	1	17.47	0.728	1:24.0
Regal.....	1910	do.....	1	16.11	.836	1:19.3
Regua.....	1910	do.....	1	16.75	.844	1:19.8
Rogers.....	1909	do.....	1	18.10	1.035	1:17.5
Rogers No. 24.....	1910	do.....	1	13.19	1.238	1:10.7
Rogers No. 32.....	1910	do.....	1	15.43	1.181	1:13.1
Rupert.....	1910	do.....	1	13.28	1.756	1: 7.6
St. Louis.....	1910	do.....	1	13.31	1.140	1:11.7
Salem.....	1909	Northern Ohio.....	1	17.61	.510	1:34.5
Do.....	1910	All northern.....	3	20.17	.828	1:24.4
Do.....	1913	New York.....	2	19.64	.604	1:21.7
Do.....	1913	New Jersey.....	1	17.41	1.085	1:16.0
Schraidt.....	1908	Northern Ohio.....	1	18.23	1.294	1:14.1
Do.....	1909	do.....	3	17.50	1.823	1: 9.6
Do.....	1910	do.....	2	18.28	1.594	1:11.5
Do.....	1911	do.....	3	18.85	1.600	1:11.8
Seibel.....	1911	New York.....	1	11.10	1.852	1: 6.0
Taylor.....	1913	New Jersey.....	2	17.57	1.326	1:13.3
Telegraph.....	1910	New York.....	1	13.90	1.256	1:11.1
Tragedy.....	1910	do.....	1	16.65	.776	1:21.5
Triumph.....	1910	do.....	1	14.09	1.354	1:10.4
Do.....	1911	do.....	1	11.09	1.012	1:11.0
Ulster.....	1913	New Jersey.....	1	19.23	.684	1:28.1
Vergennes.....	1910	New York.....	3	17.34	1.082	1:16.0
Wapanuka.....	1910	do.....	1	9.42	1.084	1: 8.7
Wilder.....	1909	Northern Ohio.....	1	14.44	1.020	1:14.2
Do.....	1910	New York.....	1	14.11	1.189	1:11.9
Winchell.....	1913	New Jersey.....	1	19.28	.506	1:38.1
Woodruff.....	1909	Northern Ohio.....	1	14.34	.409	1:35.1
Do.....	1913	New Jersey.....	1	13.54	.660	1:20.5
Worden.....	1909	Northern Ohio.....	2	17.24	.709	1:24.3
Do.....	1910	All northern.....	15	16.46	.998	1:16.5
Do.....	1911	New York.....	2	13.12	.922	1:14.2
Wyoming Red.....	1910	do.....	2	13.29	.805	1:16.5

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PROFESSIONAL PAPER

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THE CONTROL OF DAMPING-OFF OF CONIFEROUS SEEDLINGS.

By CARL HARTLEY, *Forest Pathologist*, and ROY G. PIERCE, *Forest Assistant, Office of Investigations in Forest Pathology.*

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THE DISEASE.

Damping-off is a term commonly used to describe the disease causing the death of very young seedlings due to various parasitic fungi. The damping-off of conifers in the United States has been found to be caused by the fungi *Pythium debaryanum* Hesse, *Fusarium moniliforme* Sheldon, and the common American Rhizoctonia, usually referred to as *Corticium vagum* B. and C. var. *solani* Burt. Other species of *Fusarium* and other fungi are probably also concerned to a less extent. Most affected seedlings promptly fall over and decay. Those which are not attacked till they are 4 to 8 weeks old may have such wiry stems that they merely turn brown and remain standing after death. This later type of injury is caused by parasites in the same way as the decay of the more succulent younger seedlings, though nurserymen do not always recognize it as the same thing.

ECONOMIC IMPORTANCE OF DAMPING-OFF.

Damping-off has been a handicap to nearly all nurserymen who raise conifers from seed. In most nurseries a large number of seedlings are lost every year. The loss is ordinarily considerably heavier than the nurseryman realizes. Very young seedlings decay and disappear so soon after infection that the number of dead seedlings

visible at any one time is but a small part of the total loss. Furthermore, many of the seedlings are killed immediately after the seed sprouts and before the seedlings appear above the soil surface. Many failures hitherto attributed to poor germination are in reality due to the work of the damping-off parasites in the sprouting seed, underground. The high price of most evergreen seed makes this loss of young seedlings a serious matter.

The cost of seed¹ ranges from a minimum price of 50 cents per pound for western yellow pine (*Pinus ponderosa* Laws.) collected by the United States Forest Service to \$2 to \$4 per pound quoted by commercial seedsmen for the native spruces and \$5 to \$10 per pound for Norway pine (*Pinus resinosa* Ait.). The regular annual loss is, however, not the most serious result of the disease. The most troublesome thing from the commercial standpoint is the great variation in the prevalence of the disease. In some seasons the loss is relatively slight, while in others the seed beds may be almost a total loss. The results of a damping-off epidemic are shown by the poor stand in the untreated plats in Plate I. Such epidemics make it impossible for a nurseryman to secure any regularity in production. The difficulty of controlling damping-off has caused many nurserymen to give up raising their own seedling conifers.

The loss from damping-off can not be figured merely on a basis of the number of the seedlings destroyed. The most serious aspect of the disease is the extent to which planting is discouraged by it. Reforestation of watersheds is one of the great needs of the present time. When interest on the cost of a forest plantation is compounded for the 80 or 100 years which must elapse between forest planting and timber cutting, a very slight initial increase in the cost of planting stock becomes a heavy charge against the ultimate timber value of the plantation, on which the owner must depend for direct returns. It is necessary in order to encourage forest planting to eliminate all possible cost items in the establishment of plantations. Both the average loss and the irregularity in production due to damping-off are reflected in the prices of coniferous planting stock, so that the disease must be controlled to give the maximum opportunity for profitable reforestation. It has previously been possible to import pine stock from Europe cheaply. This has resulted in the introduction of very dangerous insect and fungous pests. The importation of all pines is now prohibited, and the danger of the further introduction of parasites on imported stock of other conifers makes it necessary that the domestic nursery industry be developed on an economic scale that will eliminate all need or incentive for importation. To do this, all important native diseases, of which damping-off is the most serious, must be controlled.

¹ Information furnished by the Office of Forest Investigations, United States Forest Service.

RELATION BETWEEN NURSERY METHODS AND THE CONTROL OF DAMPING-OFF.

A great deal has been written, largely in horticultural journals, on the methods best calculated to prevent damping-off. It has been generally agreed that beds should be well drained and aerated and should have no more water or shade than absolutely necessary. Surfacing beds with gravel, coarse sand, or heated sand has also been recommended. All of these measures have value, but all have their limitations. All of them combined are not sufficient to prevent heavy losses when the damping-off parasites are present in sufficient quantity.

THE BEST SOIL FOR SEED BEDS.

In general, where there is a chance to choose between different seed-bed sites it is safest from the standpoint of damping-off control to select a site with a sandy soil. Either because such soils are better drained or because they contain less organic food matter for fungi, damping-off is commonly less troublesome on light than on heavy soils. A sandy soil is by no means a guaranty of freedom from disease, the heaviest damping-off losses in the writers' experience having occurred on a soil consisting of nearly pure sand. Alkaline soils are believed to favor damping-off. If this is found to be the case, it may explain the fact that some of the heaviest losses from damping-off occur in Nebraska and Kansas rather than in the more humid Eastern States.

Where it is necessary to put seed beds on a soil where damping-off is troublesome, the soil may be improved in various ways. Where sand is easily available, it may pay to haul it in and mix it with the surface soil. Excellent results have been obtained in one case in the writers' experience by making the entire upper 3 inches of the bed of very sandy subsoil just dug up. A less expensive procedure which has also given indication of value is to cover the seed with subsoil taken from a point so far below the surface that it is likely to be free from parasitic fungi and an unfavorable medium for their growth. It is usually better to cover seed with sand than with heavy soil, and surfacing the beds with coarse sand or gravel after the seed is sown and covered is considered helpful. Surfacing the beds after germination with heated sand applied as hot as the hand can stand has also been recommended. Tests by the writers of hot sand on seed beds in a sandy western soil had no perceptible effect on the disease.

AVOIDANCE OF EXCESSIVE MOISTURE.

To secure drainage, seed beds are commonly raised from 2 to 3 inches above the paths, and at some nurseries the surface of the bed is arched to increase run-off. This is probably good practice at most nurseries, but on very sandy soils in a dry climate it does not appear to

have any value whatever. To secure aeration the best eastern nurseries leave their beds entirely open to the wind, or, if side walls are needed to exclude seed-eating animals, they use wire netting only. Yet, at a nursery in western Kansas, after trying the rather expensive netting sides, it was found by forest officers that as good or better results were obtained by using beds with tight board sides. It is well known that excessive moisture and shade must be avoided in the seed beds. However, in sandy soils or in a dry country there is nearly as much danger of getting the beds too dry as of keeping them too wet. Drought often kills large numbers of seedlings in beds left without water.

Aside from common drought injury the effort to keep seed beds dry may result in an entirely different type of trouble. If seed beds are insufficiently shaded and the soil surface is not kept moist, there is at some nurseries serious loss from "white-spot" injury. This injury in seedlings up to 3 weeks of age appears as a whitening and shrinking of the stem just above the ground line. The shrunken area in most cases girdles the stem, the seedling falls over, and death follows. When the injury occurs on one side only it is usually the south or southwest side of the stem that is affected. The symptoms are very much like damping-off, the decided white color of the part of the stem first affected being the most noticeable difference. This white-spot injury is caused not by parasites but apparently by heat, with which possibly may also be combined the direct effects of intense light. The temperature at the surface of a dry, loose soil exposed to the sun may exceed 140° F., a very high temperature for most tender plant tissues to endure for any length of time. White-spot injury is almost always mistaken for damping-off, and has been observed to kill more than half of the seedlings in unshaded beds of even so heat-resistant a species as western yellow pine (*Pinus ponderosa*). In withholding water and shade from coniferous seed beds, nurserymen must be very careful or the loss from drought and white-spot will much exceed the advantage from decreased damping-off loss. Keeping the beds dry is impossible in wet weather and dangerous in dry weather, and it therefore will never be more than a partial control method for damping-off.

FERTILIZERS.

The relation between soil fertilization and damping-off has been but little investigated. In preliminary tests dried blood and nitrate of soda have apparently favored the damping-off parasites, and their use on pine seed beds is considered inadvisable. However, in Vermont¹ tankage has given excellent results against damping-off. It is evident that further tests of nitrogenous fertilizers are needed.

¹ Gifford, C. M. The damping-off of coniferous seedlings. Vt. Agr. Exp. Sta. Bul. 157, p. 170. 1911.

Lime in small quantities has had no appreciable effect, while applications at the rate of 1 ton per acre to beds of jack pine (*Pinus banksiana* Lamb.) in Nebraska have had bad effects. At Burlington, Vt.,¹ wood ashes have been added to seed beds with disastrous results. Lime also caused trouble at Burlington. At Providence, R. I., a mixture of coal and wood ashes tested by Prof. H. H. York seemed to give bad results. Heavy applications of imperfectly rotted horse manure have been known to greatly increase damping-off at the Nebraska nursery, but at the same nursery well-composted manure seems harmless. It is probably safest to manure beds at least a year before seed is to be sown on them. No trouble has been observed to result from the use of green manures, but it may be found that some such crops harbor damping-off parasites and should be avoided. The perennial ragweed of the Southwest (*Ambrosia psilostachya* DC.) serves as a hold-over host for parasitic strains of *Corticium*, so that this and any other weeds known to carry seedling parasites should be eliminated from nursery areas.

DENSITY OF SOWING.

As with truck crops, it is found that pines suffer most from damping-off when sown too closely. A bed containing a stand of seedlings which is too dense will not only lose more seedlings than a less crowded bed, but it will lose a higher percentage of its seedlings. This is due to the ease with which the parasites spread from one seedling to another in dense stands. It has also been found with jack pine that in tests at two nurseries the damping-off loss in seedlings sown broadcast was only four-fifths as great as in adjacent plats sown in drills. In general, beds sown broadcast seem to suffer less from damping-off than beds sown in drills, though with western yellow pine broadcasting has given no better results than the drill method at the nurseries where comparative tests were made.

TIME OF SOWING.

Another item in nursery practice in which variation may affect damping-off is the time at which seed is sown. At some nurseries it makes little difference when seed is sown. In one season beds sown in early spring suffer least from the disease. The next season the latest sown beds may come out the best. However, at some nurseries it is found that there is a best time and a worst time for seed sowing. In a New Mexico nursery it has been demonstrated that July, the local rainy season, is the worst sowing time from the damping-off standpoint. At two western nurseries (in Nebraska and Colorado) the Forest Service has found that yellow-pine seed beds sown in late autumn are comparatively free from damping-off. Repeated tests during two or three successive seasons are necessary

¹ Gifford, C. M. Op. cit.

to determine for any particular nursery whether or not damping-off losses are regularly less in beds sown at a particular time. It is thought that fall sowing is least likely to succeed in localities in which the soil does not remain constantly frozen during the winter.

TESTS OF SOIL DISINFECTION FOR THE CONTROL OF DAMPING-OFF.

The entire matter of the factors controlling the work of the damping-off parasites and the methods of seed-bed management most likely to decrease the disease needs a great deal of further examination. At present adherence to the best known nursery practice will not avoid considerable annual losses at most nurseries or prevent epidemic years in which the beds of certain species are entire failures. The multiplicity of parasites and the different conditions of soil and climate to be met so complicate the problem that it has been found most profitable to make a direct attack on the parasites by the use of disinfectants rather than wait for results by the indirect means of changed nursery management.

Experiments in seed-bed disinfection have been carried on by the writers or in pursuance of their recommendations for the past seven years and at a number of nurseries. At different times assistance has been rendered by Mr. R. D. Rands, Dr. J. V. Hofmann, Dr. T. C. Merrill, Mr. S. C. Bruner, and Mr. G. G. Hahn.

Definite and satisfactory control of the disease has been secured by soil disinfection at every nursery in which extensive experiments have been conducted, and preliminary tests at additional nurseries indicate that while different places require somewhat different procedure, damping-off everywhere can be controlled by proper disinfection of the seed beds. The economic results at all of these nurseries are briefly described in the following pages, together with a summary of the published results of other investigators.

RESULTS OF SOIL DISINFECTION AT NURSERIES WHERE REPEATED TESTS HAVE BEEN MADE.

The first tests were made in pine seed beds in the very sandy soil of the United States Forest Service nursery at Halsey, Nebr. The experience at this nursery was in many ways typical and will therefore be described in some detail.

The first attempt was to control the disease by applying disinfectants after the seedlings appeared above ground. This failed, partly because the disinfectants injured the seedlings and partly because the parasites were found to do a great deal of their work before the seedlings came up. A number of disinfectants were then tested in applications at or before seed sowing. Of these, commercial sulphuric acid appeared the cheapest and most effective. Both heat and formaldehyde, the means usually recommended for disinfecting greenhouse and truck soils, proved less reliable as well as more expensive.

The treatment finally adopted consists of three-sixteenths fluid ounce of sulphuric acid per square foot of seed bed, applied in solution immediately after the seed is sown and covered. The amount of water used to dissolve the acid varies from 1 pint per square foot when the soil is wet to 2 pints when the soil is dry. In all disinfection of seed beds by chemicals the quantity of the disinfectant used per unit area of soil surface seems to be the important variable. The disinfectant must be dissolved in sufficient water to permit its distribution through the soil to a depth of several inches, but within certain limits the concentration of the solution as applied does not appear to be an important factor. The adherence of some investigators to the concentration of the solution used as a measure of soil treatment makes their work difficult to correlate.

In the earlier tests of acid at Halsey chemical injury to the pines occurred in beds treated with acid at the time of sowing. It was found that dormant pine seeds were not injured by acid, but that the root tips of the seedlings in acid beds were often killed just after germination commenced. The way in which this injury occurred made it evident that it was due to the concentration of the acid in the surface soil. Evaporation of water from the soil surface seemed to bring up the disinfectant from the lower soil, just as alkali salts come to the surface in alkali soils. Watering the beds frequently during the germinating period prevents such surface concentration and in practice has been found entirely to prevent injury to the seedlings. The method of protecting the seedlings from acid injury at this nursery is to water the seed beds frequently from the time seed is sown until a few days after germination, when the root tips have penetrated one-half inch into the soil. After this time they are practically safe from further injury. The beds are watered daily in ordinary spring weather, every other day in misty or rainy weather, and twice daily when the maximum temperature exceeds 80° F. In clear weather each watering is at the rate of approximately 1½ pints per square foot of bed. In cold, cloudy weather 1 pint per square foot is found sufficient. (Two-tenths inch of rainfall is equivalent to 1 pint per square foot.)

The acid treatment was repeatedly tested on different species of pine during different years and at different times of the year. In all cases it resulted in increased stands. The results of all the acid tests in which the above watering system or its equivalent was followed are given in Table I.

In addition to the three species given in this table, a test on a series of plats of Corsican pine (*Pinus laricio* Poir.) gave excellent results; an accident prevented the securing of exact figures. Some of the tests included in the table were conducted on a considerable scale, the total area involved being 8,350 square feet in the treated

plats and 547 feet in the untreated plats. In the case of the larger plats, counts of seedlings were made only on sample areas scattered through the plats. The percentages of germination and of death are based on counts of all seedlings on 246 square feet in the treated plats and 145 square feet in the untreated plats. The surviving seedlings were counted on these sample areas and also on additional areas, totaling 406 square feet for the acid plats and 196 square feet for the untreated plats. Damping-off is so variable that only repeated and extensive tests of this sort are entirely reliable.

TABLE I.—*Control of damping-off of pines by three-sixteenths fluid ounce of sulphuric acid per square foot of seed bed applied at sowing time, Halsey, Nebr.*

Species.	Number of separate tests.	Treatment.	Absolute results.			Relative results.		
			Germination. ¹	Death per hundred seedlings. ²	Final stand based on seed sown.	Germination. ^c	Death.	Final stand.
			<i>Per cent.</i>		<i>Per cent.</i>			
Pinus banksiana ³	11	Acid.....	32.7	15.2	26.4	161	35	267
		None.....	20.3	43.7	9.9	100	100	100
P. ponderosa.....	3	Acid.....	66.3	12.0	58.7	132	33	178
		None.....	59.3	36.7	33.0	109	190	100
P. resinosa.....	3	Acid.....	70.0	28.7	40.7	112	53	254
		None.....	62.7	73.7	16.0	100	100	100
Average ³	17	Acid.....	56.3	22.0	41.9	135	43	233
		None.....	44.4	51.4	16.3	100	100	100

¹ The germination percentage takes into account only seedlings which appear above the soil. Seeds which started to germinate but did not reach the point of breaking through the soil are not included.

² The death percentage includes all seedlings which died from damping-off and also any which may have died from drought or chemical injury after the seedlings came up. Seedlings broken by hail or other mechanical means or killed by insects are not included.

³ Germination and death figures obtained from only 9 of the 11 jack-pine tests.

The acid in practically all cases caused a marked increase in the number of seedlings that came up, as well as a decrease in the death rate after coming up. Damping-off was not entirely controlled. There was still a loss of 22 per cent after germination in the treated plats, but the loss in the untreated plats was nearly two and one-half times as great. The combined effect of increased germination and decreased death rate was a large increase in the number of healthy seedlings produced. (See Table I, columns headed "Final stand.")

It is especially to be noted that in jack pine and Norway pine, the species with which the most extensive tests were made, more than 250 healthy seedlings were obtained in the treated plats for every 100 obtained from equal quantities of seed in the untreated plats. The results of the acid treatment of Norway pine are strikingly shown by the difference in stand in the treated and untreated plats shown in Plate I, figure 1.

Since the foregoing tests were conducted, the acid treatment has been put into regular use on all spring-sown beds at this nursery and the success of the treatment further confirmed by the continued good results secured.

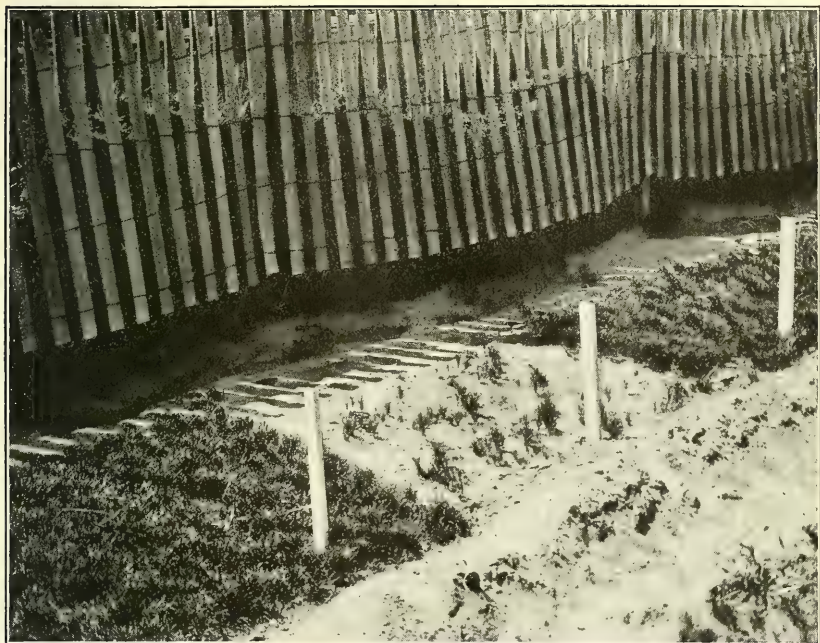


FIG. 1.—NORWAY-PINE SEED BED, 1 YEAR OLD, HALSEY, NEBR.

Plat in center untreated. Remainder of bed treated at time of sowing with a solution containing three-sixteenths fluid ounce of sulphuric acid per square foot of bed. Practically all of the seedlings in the untreated plat have been destroyed by damping-off. Photographed by Charles B. Pool (F 1).

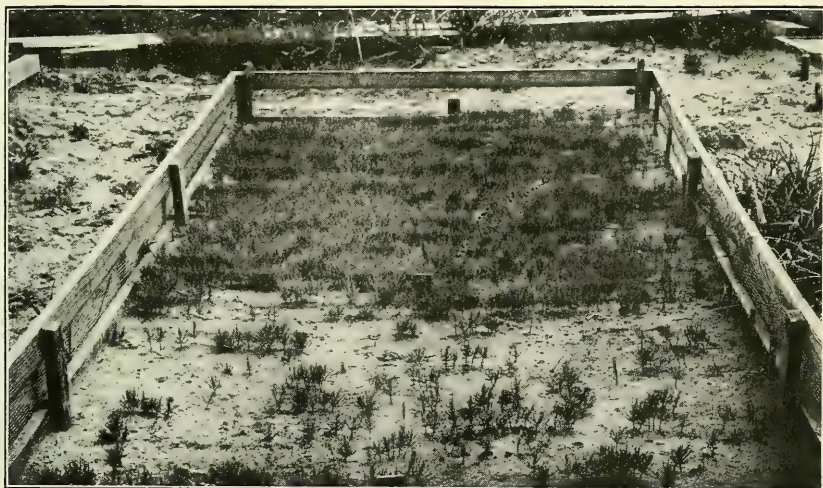


FIG. 2.—WESTERN YELLOW-PINE SEED BED, KANSAS SANDHILLS.

Foreground untreated. Background treated at time of sowing with a sulphuric-acid solution. Most of the seedlings in the untreated plat have been destroyed by damping-off. Photographed by Dr. J. V. Hofmann (F 2).

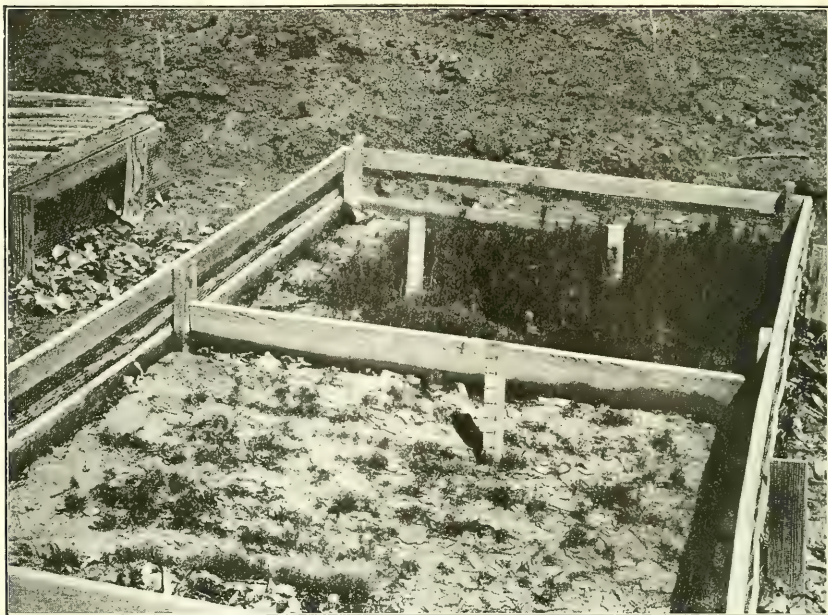


FIG. 1.—JACK-PINE SEED BED, GARDEN CITY, KANS.

Foreground untreated. Background treated with sulphuric-acid solution before germination. Stakes marked in inches. Note the difference in height of the seedlings after the first season's growth (F 3).

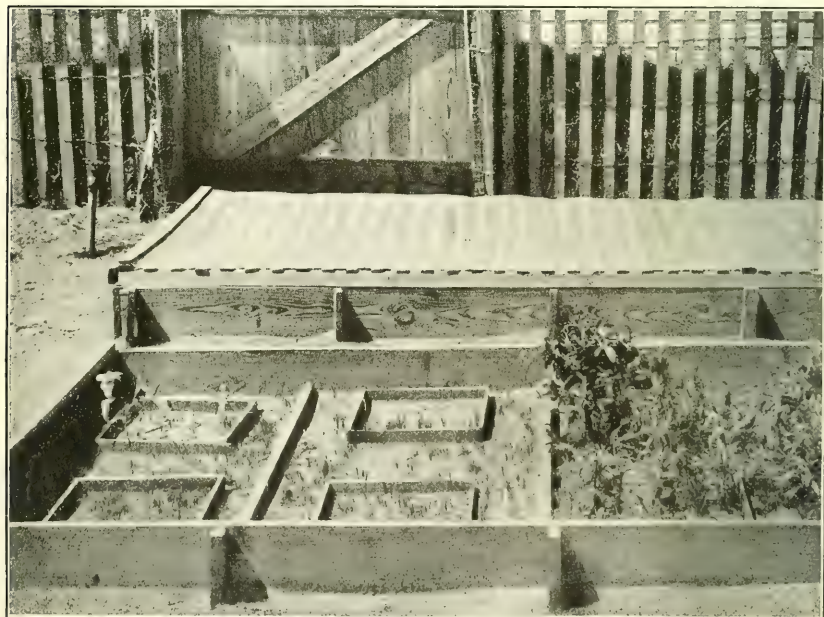


FIG. 2.—JACK-PINE SEED BED, KANSAS SANDHILLS.

Plat at left treated with one-fourth ounce and plat at center with three-eighths ounce of sulphuric acid per square foot. Plat at right untreated. Note the relative freedom from weeds in the treated plats. The apparently thin stand of trees in the treated plats is due to the very small size of the young seedlings of this species of pine. Actual counts in these plats showed the stand to be as dense as can be grown without subsequent overcrowding. Photographed by Stephen C. Bruner (F 4).

At nearly all of the other nurseries sulphuric acid was also found successful in controlling damping-off. However, because of differences in soil and climate, the treatments required elsewhere differed in some details from that at Halsey. On a still lighter sand in Kansas sand hills, which was probably also somewhat more alkaline, it was found that damping-off could be controlled best by a heavier treatment of acid—one-fourth fluid ounce per square foot in ordinary spring-sown beds, and five-sixteenths or three-eighths ounce in beds sown in the fall or very early spring. The watering required during the germinating period to prevent injury to the pines was less than at Halsey. The losses in untreated beds at this nursery were exceptionally heavy. In the treated beds it was not possible to reduce the damping-off loss to as low a figure as at Halsey, probably because of the common occurrence of *Fusarium moniliforme*, a fungus exceptionally able to quickly reinfect treated beds. The success of the treatment from the economic standpoint, however, was greater than at Halsey. Without the treatment, failure occurred in the seed beds more often than success, and stock could not be raised at a reasonable expense. With the treatment, success was the rule, and the economical production of stock became possible. The difference in stand between treated and untreated plats at this nursery is shown in Plate I, figure 2.

At a single nursery on a fine sandy soil near Morrisville, Pa., it was found that it was more difficult than at Halsey to prevent acid injury to germinating seedlings. This was a nursery at which tests were made during a single season only. It is mentioned at this point merely to show the difference in behavior of acid in different soils. Even one-twelfth fluid ounce per square foot caused injury to the pines at Morrisville. Indications from the small series of tests conducted there were that one-eighth ounce of acid per square foot would probably prove effective against damping-off and harmless to coniferous seedlings if followed by sufficiently frequent watering during the germinating period. It is likely that this soil was slightly acid to start with.

In marked contrast to the experience at Morrisville are the results obtained at Fort Bayard, N. Mex., Monument, Colo., and Haugan, Mont. At all of these places acid at the rate of three-sixteenths ounce or more per square foot has been applied to the beds at sowing in repeated tests, without any injury to the seedlings that could be detected by the forest officers in charge at the nurseries. At Fort Bayard Mr. H. C. Turner has tested the acid very thoroughly for four successive seasons and in quantities up to five-eighths ounce per square foot without finding any injury to seedlings. Even three-sixteenths ounce proved reasonably efficient in decreasing damping-off, and the five-eighths ounce treatment reduced the loss to less than 1 per cent.

At Haugan the acid has been used for three years and damping-off has been practically abolished in the beds treated. These three nurseries differ from the preceding three in that the soil is heavier and there is no need of any extra watering in order to prevent chemical injury to the seedlings.

At a seventh nursery an entirely different condition was encountered. The seed beds were located on a rather heavy soil near Garden City, Kans. This soil effervesced vigorously when treated with acid, yielding 0.23 per cent of carbon dioxid from the surface soil and over 1 per cent from the subsoil in a test made by the Bureau of Soils. Acid treatments had no effect on damping-off in this soil, owing presumably to the high carbonate content and consequent alkalinity which the effervescence indicated. Tests with copper sulphate, one-fourth ounce per square foot, and zinc chlorid, one-half ounce per square foot, showed that both these and heavier treatments were effective against damping-off. The results are given in Table II.

TABLE II.—Control of damping-off of pines by one-fourth to three-fourths ounce copper sulphate and one-half to one ounce zinc chlorid per square foot of seed bed, Garden City, Kans.

Species and time of sowing.	Disinfectant.	Number of separate tests.	Absolute results.			Relative results.		
			Germination.	Death per hundred seedlings.	Final stand based on seed sown.	Germination.	Death.	Final stand.
Pinus austriaca:	{ Copper sulphate... None..... }	2	<i>Per ct.</i> 40.1	59.0	21.3	254	65	1,638
			15.8	91.0	1.3	100	100	100
	{ Zinc chlorid..... None..... }	1	37.5	99.0	.5	192	99	(a)
			19.5	100.0	0	100	100	(a)
P. banksiana:	{ Copper sulphate... None..... }	3	27.1	35.2	16.1	105	56	212
			25.9	62.3	7.6	100	100	100
	{ Zinc chlorid..... None..... }	3	30.7	27.6	21.0	130	40	362
			23.7	69.0	5.8	100	100	100
	{ Copper sulphate... None..... }	2	16.6	67.8	9.0	143	101	143
			11.6	67.0	6.3	100	100	100
	{ Zinc chlorid..... None..... }	2	37.5	20.0	28.9	264	30	452
			14.2	66.0	6.4	100	100	100
	{ Copper sulphate and zinc chlorid. None..... }	-----	28.0	37.7	18.8	148	57	289
			18.9	66.1	6.5	100	100	100
P. ponderosa:	{ Copper sulphate... None..... }	2	46.1	20.1	34.8	113	34	217
			40.9	59.8	16.0	100	100	100
	{ Zinc chlorid..... None..... }	2	42.9	16.1	33.1	117	28	183
			36.6	57.4	18.1	100	100	100
	{ Copper sulphate... None..... }	8	58.1	24.0	42.2	114	53	147
			50.9	45.1	28.7	100	100	100
	{ Zinc chlorid..... None..... }	6	61.3	b 11.8	46.6	116	30	150
			52.7	b 39.1	31.0	100	100	100
	{ Zinc chlorid and copper sulphate. None..... }	-----	52.1	18.0	39.2	115	36	167
			45.3	50.4	23.5	100	100	100

a No expression possible. b The damping-off percentage was determined in but five of the six tests.

Copper sulphate could probably have been used with success in quantities less than one-fourth ounce per square foot. A three-eighths ounce zinc-chlorid treatment proved unsuccessful. Both disinfectants were dissolved in water and applied in most cases just after seed sowing, as was done with acid. Both were found harmless to the dormant seed in these concentrations, but both were capable of injuring germinating seedlings in just the same way as is described for acid at Halsey. This injury was prevented by extra watering during the germinating period, in the same way as acid injury was prevented at the Halsey and Kansas sand-hill nurseries. The amount of this extra watering needed at the Garden City nursery was very slight.

An interesting thing that developed at this nursery, as well as at the Kansas sand-hill nursery, was the control of spring damping-off by treatments applied during November of the preceding year. Part of the fall-sown plats whose results were shown in Table II were treated at the time of sowing and part as soon as the soil thawed the following spring. Though the seedlings did not appear until the following April, disinfectants applied in November seemed to protect them from damping-off as well, or practically as well, as disinfectants applied in March. At this nursery and at the five preceding at which repeated tests were made, the treatments developed have been put into regular large-scale use by the nurserymen, with good results.

**RESULTS OF SOIL DISINFECTION AT NURSERIES WHERE TESTS HAVE BEEN LIMITED
TO A SINGLE SEASON.**

At Porvenir, N. Mex., Dundee, Ill., Lincoln, Nebr., the nursery of the State Board of Forestry in Vilas County, Wis., and the greenhouses of the United States Department of Agriculture at Washington, D. C., single-season tests of sulphuric acid have given good results. At all of these places no need was found for any special watering provision for the prevention of chemical injury from the acid. The tests at Dundee and Lincoln were made during an unusually rainy season. It may develop that in years with less rain more watering will be needed at these places.

At four other nurseries where disinfectants were tested in this preliminary way the results were less definite. At Morrisville, Pa., already referred to, there was distinct evidence that a very weak acid treatment with sufficient watering during the germinating period will be entirely successful in controlling the small amount of damping-off which normally occurs there. One-eighth ounce of acid per square foot it is thought will be sufficient. Insufficient watering prevented the securing of exact information from the tests conducted. At Pocatello, Idaho, a single test of acid on beds of Douglas fir had no conspicuous effect on the amount of damping-off. As the soil is found to effervesce on the addition of acid, success with acid does not

appear probable. At Cass Lake, Minn., acid was tested on seed beds of Norway pine (*Pinus resinosa*) during a period of weather so abnormally cold and wet that the seed lay in the ground for a number of weeks before germination was completed. Under these conditions, for the first time in the writers' experience, the acid treatment of the beds at the time of sowing resulted in decreased germination. No special watering was needed to prevent injury to the tips after the seedlings began to come up; in fact, very frequent watering given one bed resulted in less germination and therefore poorer results than in acid beds with no extra watering. Despite the decrease in germination, the acid beds, because of the almost complete control of damping-off by the treatment, finished the season with an average of 135 seedlings for every 100 in the untreated plats, and the acid plats which were not given excessive water had 151 seedlings for every 100 in the untreated plats. This fact and the fact that acid beds which had first been treated with lime and were thereby kept from injury to the seed produced 228 seedlings for every 100 in the untreated plats indicate that in ordinary seasons the treatment with acid alone will be entirely successful. The use of lime with acid is usually undesirable because by neutralizing the acid it permits the parasites to resume work soon after treatment. Formaldehyde gave better results than acid at Cass Lake. While it is thought that this would not be the case in a normal season, it is evident that further tests are needed to determine what treatment to use.

The danger in drawing conclusions from the results of three or four test plats is shown especially well by the results obtained by Prof. H. H. York, of Brown University, in testing treatments recommended by the writers. Treatments involving five-sixteenths ounce of sulphuric acid, five-eighth ounce of zinc chlorid, and $2\frac{1}{2}$ ounces of cane sugar, respectively, per square foot of bed, resulted in final stands from $4\frac{1}{2}$ to 15 times as dense as in most of the untreated plats. One untreated plat, however, gave a stand as dense as that on the treated plats. This throws doubt on the reliability of the results on the other plats and indicates that only repeated tests, each with plenty of untreated plats for abundant comparison, are reliable enough to be used as a basis for conclusions.

At several of the nurseries mentioned above other soil treatments were tried with success. At Glenview, Ill., where acid failed, copper-sulphate treatment resulted in doubling the final stand. The good results obtained on otherwise untreated soil at Dundee, Ill., by the addition of cane sugar were rather surprising; indications of damping-off control by sugar were also observed at Garden City, Kans., East Tawas, Mich., and Providence, R. I. Further tests are required. At East Tawas, a test of acid in an unfavorable season did not give as good results as desired, while formaldehyde resulted in a doubled stand.

RESULTS OF SOIL DISINFECTION IN GREENHOUSE TESTS.

In the greenhouses of the Department of Agriculture at Washington, D. C., disinfection of soil by steam pressure has proved reasonably effective in controlling damping-off of pine seedlings in most of a rather large number of tests conducted during the winter months. During the summer there is so much reinfection that the results of heat disinfection are uncertain. A single test of sulphuric acid in the spring of 1915 indicated the value of acid treatment in reducing damping-off in the greenhouse. Four flats of jack pine were treated with sulphuric acid in quantities of three-sixteenths to three-eighths ounce per square foot just after sowing. The relative survival in the acid flats, taking the average survival in the untreated flats as 100, was 128. The relative survival in flats disinfected by steam was only 105. Three-sixteenths ounce of acid per square foot gave as good results as heavier treatments. The soil used in this experiment was a mixture of seven parts loam, four parts sand, two parts manure, and one part leaf mold.

RESULTS IN DISINFECTING THE SOIL OBTAINED BY OTHER INVESTIGATORS.

Spaulding,¹ who appears to have been the originator of the use of sulphuric acid for soil disinfection, has tested acid and other disinfectants at several places. In greenhouse tests formaldehyde and copper sulphate were found valuable, but the sulphate injured seedlings. At Saranac Inn, N. Y., formaldehyde apparently increased damping-off one season and controlled it in a later season, while sulphuric acid injured seedlings and gave results which from the economic standpoint were inconclusive.

At Burlington, Vt., results with disinfectants in pine-seed beds have been reported by Spaulding,² Jones,³ Gifford,⁴ and Burns.⁵ Formaldehyde applied five days before sowing and allowed to evaporate for two days before sowing killed part of the seed. All of the writers found formaldehyde of decided value in controlling damping-off. Jones and Spaulding report a single test in which but one-tenth ounce (0.106 ounce) of formaldehyde was used per square foot and excellent results obtained. The subsequent tests reported have been with amounts of 0.48 ounce or over per square foot. The treatment used by Burns, of 0.58 ounce of formaldehyde per square foot, applied

¹ Spaulding, Perley. The damping-off of coniferous seedlings. *In* *Phytopathology*, v. 4, no. 2, p. 73-88, 2 fig., pl. 6. 1914.

— The treatment of damping-off in coniferous seedlings. U. S. Dept. Agr., Bur. Plant Indus. Circ. 4, 8 p. 1908.

² Spaulding, Perley, 1914. *Op. cit.*

³ Jones, L. R. The damping-off of coniferous seedlings. *In* *Vt. Agr. Exp. Sta. 20th Ann. Rpt.*, 1906-7, p. 342-347. 1908.

⁴ Gifford, C. M. The damping-off of coniferous seedlings. *Vt. Agr. Exp. Sta. Bul.* 157, p. 141-171, 10 fig., 4 pl. 1911.

⁵ Burns, G. P. Studies in tolerance of New England forest trees. I. Development of white pine seedlings in nursery beds. *Vt. Agr. Exp. Sta. Bul.* 178, p. 125-144, 2 fig., 4 pl. 1914.

11 days before sowing, with the beds tightly covered during the interim, appears to have been entirely harmless and very effective against the disease. Burns found the sulphuric-acid treatment used by the writers at Halsey, three-sixteenths ounce per square foot applied at time of sowing, as effective as the formaldehyde and non-injurious. Spaulding,¹ reporting tests made in 1907 and 1908, also obtained excellent results with acid, which was not tested by Jones and Gifford. He in addition obtained good results in preliminary tests with copper sulphate and with sulphur.

Acid was also used at an unnamed locality by Güssow,² with excellent results.

Charcoal, an amendment rather than a disinfectant, is reported by Retan³ to be of value against damping-off in the clay soil at Mont Alto, Pa., and to result in the increased size of pine seedlings. A layer 3 inches deep was spaded into the soil. Annual treatment with this amount would, of course, be impracticable. However, Retan states that the effect of such charcoal addition is permanent. Further experience seems necessary to confirm the permanent value of charcoal for preventing damping-off on this and other soils. A single test by the writers of a lighter application of charcoal at the Cass Lake nursery proved unsuccessful.

SOIL-DISINFECTION TESTS SUMMARIZED.

The writers' experience with soil disinfectants at the different nurseries, as well as the experience of other experimenters, has been so varied that it is rather difficult to correlate the results. Correlation will be made easier by reference to Table III, in which are summed up all of the successful tests of treatments of coniferous seed beds of which the writers have been able to learn. In the tests at Halsey, the Kansas sand hills, Garden City, Lincoln, Cass Lake, Dundee, Glenview, and East Tawas, the experimental treatments were applied by the writers or their assistants, with the cooperation of those in charge of the nurseries. At Fort Bayard the tests were conducted by Mr. H. C. Turner, at Monument by Mr. W. H. Schrader, at Porvenir by Mr. H. D. Burrall, at Pocatello by Mr. Arthur P. Say, in Vilas County, Wis., by Mr. W. D. Barnard, at Providence by Prof. H. H. York, at Morrisville under the direction of Mr. John Foley, and at Haugan by forest officers, following recommendations made by the writers.

¹ Spaulding, Perley, 1914. Op. cit.

² Güssow, H. T. Diseases of forest trees. *In* Com. Conserv. Canada, Rpt. 1st Ann. Meeting, 1910, p. 136-137. 1910.

³ Retan, G. A. Charcoal as a means of solving some nursery problems. *In* Forestry Quart., v. 13, no. 1, p. 25-30. 1915.

TABLE III.—*Tests of soil treatments for the control of damping-off of conifers.*

AT PLACES WHERE REPEATED TESTS HAVE BEEN MADE.

Locality, soil type, and species used.	Successful treatments.					Important treatments which indicated—			Remarks.
	Treatment.		Number of independent tests.	Resulting stand. ¹	Amount per square foot indicated as best. ²	Extra watering needed. ²	Less value.	No value.	
	Substance added.	Amount used per square foot.							
1	2	3	4	5	6	7	8	9	10
Halsey, Nebr.; fine sand: Pines, 3 species.....	Sulphuric acid.....	Ounces, $\frac{1}{16}$	17	233	Ounces, $\frac{3}{16}$	Yes.....	Formaldehyde, copper sulphate, and heat.		Preliminary tests indicate value for zinc chlorid; degree of value not determined.
Kansas sand hills; fine sand: Pines, 4 species.....	do.....	$\frac{1}{4}$ to $\frac{3}{8}$	14	316	$\frac{1}{4}$ to $\frac{5}{16}$	Yes.....	Formaldehyde and heat.		Preliminary tests indicate value for copper sulphate and zinc chlorid.
Garden City, Kans.; fine sandy loam, with high carbonate content: Pines, 3 species.....	Copper sulphate. Zinc chlorid.....	$\frac{1}{4}$ to $\frac{3}{8}$ $\frac{1}{2}$ to 1	17 14	229 214	$\frac{1}{8}$ to $\frac{5}{16}$ $\frac{1}{2}$	Yes..... Yes.....	do.....	Sulphuric acid.....	
Fort Bayard, N. Mex.; heavy loam: Western yellow pine.....	Sulphuric acid..... Zinc chlorid.....	$\frac{1}{16}$ to $\frac{3}{8}$ $\frac{3}{8}$ to 1	10 4	143 149	$\frac{1}{4}$ to $\frac{3}{8}$ $\frac{3}{8}$	No..... (³).....	Formaldehyde.....		Copper sulphate tested with good results; exact value not determined.
Monument, Colo.; loam: Western yellow pine, Douglas fir, Engelmann spruce.....	Sulphuric acid.....	$\frac{1}{8}$	5	177	$\frac{1}{4}$ to $\frac{1}{2}$	(³).....			
Haugan, Mont.; loam: Western yellow pine.....	do.....	$\frac{1}{16}$	3 years.	(⁴)	$\frac{1}{16}$	No.....			No counts; disease control reported practically perfect.
Burlington, Vt.: Pines, 3 species.....	Formaldehyde..... Sulphuric acid..... Tankage.....	$\frac{1}{16}$ to 1 $\frac{1}{16}$ $\frac{1}{2}$	Results of other investigators.	{	$\frac{1}{4}$ to $\frac{3}{8}$ $\frac{3}{8}$ $\frac{3}{16}$ <				

¹ Number in treated plats for each 100 in untreated.² To prevent chemical injury.³ Probably not.⁴ See under "Remarks."

TABLE III.—*Tests of soil treatments for the control of damping-off of conifers—Continued.*

AT PLACES WHERE TESTS HAVE BEEN LIMITED TO A SINGLE SEASON.

Locality, soil type, and species used.	Successful treatments.					Important treatments which indicated—			Remarks.
	Treatment.		Number of independent tests.	Resulting stand, ¹ per square foot.	Amount per square foot indicated as best.	Extra watering needed. ²	Less value.	No value.	
	Substance added.	Amount used per square foot.							
1	2	3	4	5	6	7	8	9	10
Porvenir, N. Mex.; sandy loam: Engelmann spruce.....	Sulphuric acid...	Ounces, $\frac{5}{8}$ to $\frac{3}{4}$	2	168	Ounces, $\frac{5}{8}$ to $\frac{3}{4}$	(3).....	Zinc chloride.....	Formaldehyde and copper sulphate. Sulphuric acid.....	Soil contains carbonates.
Pocatello, Idaho; loam: Douglas fir.....									
Lincoln, Nebr.; very sandy loam: Norway spruce, blue spruce, and western yellow pine.	Sulphuric acid...	$\frac{5}{8}$ to $\frac{7}{8}$	2	130	$\frac{5}{8}$	(3).....	Zinc chloride.....		
Cass Lake, Minn.; sand: Norway pine.....	Sulphuric acid... Formaldehyde... Followed by sulphuric acid.	$\frac{1}{8}$ to $\frac{3}{8}$ $\frac{1}{4}$ to $\frac{1}{2}$ $\frac{1}{16}$ to $\frac{3}{8}$	4 1 1	135 240 228	$\frac{1}{8}$ to $\frac{3}{8}$ $\frac{1}{4}$ to $\frac{1}{2}$ $\frac{1}{4}$	(3)..... No..... No.....	Heat, zinc chlorid, copper sulphate, and charcoal (light treatment).	Sulphur.....	{ For explanation of low figure for acid treatment, see p. 12.
Vilas County, Wis.; fine sand: Pine.....	Sulphuric acid...	$\frac{1}{8}$	1	147	$\frac{1}{8}$	(3).....			

Dundee, Ill.; loam (mostly treated with marl):	4 4	140 145	(3) No.	Zinc chlorid (when used alone).	(Formaldehyde (when used alone), cane sugar (on marled soil).	Zinc chlorid following formaldehyde was dissolved in only three-fourths pint of water per square foot of bed.
Austrian pine.....	2 1	177 181	No. No.			
Glenview, Ill.; sandy loam: Douglas fir, hemlock....	2	201	(4)		Sulphuric acid and zinc chlorid.	
East Tawas, Mich.; fine sand: Norway pine and white pine.	2	200		Sulphuric acid.		
Providence, R. I.; sandy loam:	1	(4)	Yes	Formaldehyde.		Value indicated, especially for acid and zinc chlorid; extent not determined.
Morrisville, Pa.; fine sandy loam:	1 1 1	(4) (4) (4)	Yes Yes No.			Value indicated; extent not determined.
Fines and Norway spruce	1	(4)	Yes			
Greenhouse, Washington, D. C.; sandy loam: Jack pine.....	1	128	(4)	Heat.		Results of Spaulding.
Greenhouse, St. Louis, Mo...			No.			Do.
Saranac Inn, N. Y.; sandy...			Yes			Results of Glissow; effect described as excellent.
Canada.....			No.			Results of Retan; damping-off apparently decreased.
Mont Alto, Pa.; clay.....	Layer 3 inches thick.		Yes			

¹ Number in treated plats for each 100 in untreated.² To prevent chemical injury.³ Probably not.⁴ See under "Remarks."

In most of the treatments listed in Table III the substance used was applied just after the seed was sown and covered. Formaldehyde kills some of the seed if so used and was accordingly applied several days before seed sowing. Either the soil was treated a week or more before sowing in the formaldehyde plats and kept covered with heavy paper for a few days after treatment, or else the treatment was made but two or three days before sowing and no paper was used. Even with these precautions part of the seed was killed in the tests at Burlington, the Kansas sand hills, and Glenview. Zinc chlorid killed the dormant jack-pine seed in two heavily treated plats at Garden City which were sown and treated in the fall and remained dormant throughout the winter. It ordinarily produces no such effect. Sulphuric acid has also shown a tendency to decrease the germination percentage in two or three tests of fall treatments, but ordinarily has no such effect in spring-sown beds. It has never had more than a slight delaying effect on germination except during very wet, cold weather, and its harmful effect on dormant seed in spring-sown beds is negligible. Copper sulphate shows even less tendency than sulphuric acid to injure dormant seed. Sulphuric acid, copper sulphate, and zinc chlorid are all inclined in some soils to injure the root tips of seedlings just after germination begins; on such soils the injury to seedlings can be prevented by very frequent watering during the germinating period. Column 7 of Table III indicates for the best strength of each successful treatment whether or not such extra watering is required. It will be noted that in formaldehyde beds extra watering is nowhere necessary. For the other three disinfectants it is more commonly necessary on very light sandy soils than on heavy soils.

Air-slaked lime, powdered sulphur, and charcoal were applied dry, and in the tests reported by the writers were raked into the upper 3 inches of soil. Copper sulphate was applied in the form of dry powder in the tests reported by Spaulding.¹ Sulphuric acid, formaldehyde, zinc chlorid, and in the tests reported by the writers copper sulphate were applied in solution. The strength of all treatments is expressed in the number of ounces of substance per square foot of bed. For sulphuric acid and formaldehyde the fluid ounce (29.574 c. c.) is the unit of measure, while for all other substances the avoirdupois ounce (28.35 gm.) was used. Three-fourths of an ounce per square foot is practically equivalent to 1 ton per acre. The amount of water used in dissolving the disinfectants varies from 1 to 2½ pints per square foot. For a soil already wet 1 pint is sufficient; for a dry fine-textured soil 2½ pints may be needed to secure a proper distribution of the disinfectant. Ordinarily, 1½ or 1¾ pints per square foot are satisfactory.

¹ Spaulding, Perley. The treatment of damping-off in coniferous seedlings. U. S. Dept. Agr., Bur. Plant Indus. Circ. 4, 8 p. 1908.

COST OF DISINFECTANT TREATMENTS.

Because of the differences between the nurseries where tests have been made, both in the details of the treatment used and in the scale of the operations and the equipment of the nursery in such matters as water supply, it is impossible to make any statement as to the exact costs of treatment.

At two of the nurseries (Fort Bayard, N. Mex., and Haugan, Mont.) mentioned in the foregoing pages, at which the treatments have been in use long enough to permit a definite statement, all that is needed is an application of acid solution to the beds just after sowing. The treated beds thereafter require no more attention than do those untreated. At six other nurseries, where the acid has been in use for a less time, the same appears to be true, while for a seventh nursery, where copper sulphate gives the best results, the same simple method of application appears satisfactory. For these nine nurseries, then, the treatment which has so far appeared most effective involves no expense except that of the single disinfectant application. Different amounts of disinfectant are required for different soils, and because of the rather high cost of transporting sulphuric acid the price of that disinfectant varies greatly in different localities, so that exact costs of the treatment can not be given. It is very evident, however, that both the sulphuric-acid and the copper-sulphate treatments applied in this way are decidedly cheaper than either the formaldehyde or heat disinfection methods as used in out-of-door seed beds of tobacco and other truck crops. At many railroad centers sulphuric acid can be obtained in carboy lots for $2\frac{1}{2}$ cents per pound¹ or even less, while copper sulphate should not ordinarily exceed 8 cents per pound.¹ With copper sulphate one-fourth avoirdupois ounce and sulphuric acid one-fourth fluid ounce per square foot will be sufficient or more than sufficient at most nurseries. Judging from the experience of truck-crop experimenters and from the results of the writers and others with formaldehyde at several nurseries, one-fourth to one-half fluid ounce per square foot of the more expensive formaldehyde will be needed on most soils to secure sufficient disinfection. If it develops that it is necessary to use the tight cover prescribed by most writers to prevent premature evaporation and to treat additional soil for use in covering the seed after sowing, these items will further increase the expense of formaldehyde treatment. The expense of steam disinfection of out-of-door seed beds of tobacco is given by Johnson² as \$7.50 to \$10 per thousand square feet of bed. This is a much higher cost than is to be anticipated with acid or copper-sulphate treatment.

¹ These prices prevailed prior to the outbreak of the European war. It is assumed that the present higher prices are temporary.

² Johnson, James. The control of diseases and insects of tobacco. Wis. Agr. Exp. Sta. Bul. 237, p. 10, 1914.

Sugar, at first glance an excessively expensive amendment for use on soil, is not so much more expensive than formaldehyde in the quantities which appear of value in preventing damping-off at three of the nurseries. If some unrefined sugar-bearing substance could be substituted for the table product used in the experiments, it is entirely possible that for certain soils sugar would become an economically satisfactory treatment for coniferous seed beds. Zinc chlorid also, while probably somewhat more expensive than formaldehyde, is not so costly as to be economically impossible on soils where it may prove to be the most effective disinfectant. Both of these substances are, however, decidedly more expensive than sulphuric acid or copper sulphate.

The most troublesome thing about the treatment with acid is that at some nurseries it is necessary to give treated beds frequent waterings during the germinating period for the protection of the roots of the seedlings against chemical injury. This has been found to be the case in acid plats at three nurseries, and with copper and zinc salts at one nursery, respectively, where these disinfectants have given evidence of greatest commercial value. At one of these nurseries (Halsey, Nebr.) figures are available which indicate the cost of the treatment with acid and subsequent watering. The additional labor cost of the seed sowing, due to the use with it of the acid application, was furnished by the forest officers. The figures follow.

Additional cost of seed beds at Halsey, Nebr., due to acid treatment, per 1,000 square feet (space occupied by paths excluded).

Cost of acid (allowing for freight, drayage, and waste).....	\$1.00
Additional labor in seed sowing, due to application of acid.....	.80
Labor cost of extra waterings required by acid beds during germinating period.....	2.70
Depreciation of containers for applying acid solution, and increased supervisory cost (estimated), not to exceed.....	.50
Total charge against treatment.....	5.00

The above figures were obtained in 1912. Subsequent changes in nursery practice have probably changed the costs, but no later figures are available.

This cost of \$5 per 1,000 square feet, or one-half cent per square foot of seed bed, would seem very high if put on an acreage basis. For extensive farming operations it would, of course, be excessive. But because of the very high cost of coniferous seed and the very small area on which the seed-bed operations of even a large nursery are usually concentrated, this cost is easily offset by even a slight increase in the stand of seedlings secured. The actual cost of production of seedlings is seldom less than 50 cents per thousand by the end of the first growing season. The prices commonly quoted by commercial nurseries for seedlings of most species which have remained in the

seeded bed for a second year run from four to ten times this figure. If the minimum stand commonly desired, i. e., 100 seedlings per square foot, is obtained on untreated beds, an increase in stand of only 20 per cent will mean an increased production of 20,000 seedlings, of a minimum value of \$10 for the 1,000 square feet taken as a unit. Even in this minimum case, therefore, the treatment may be considered to have paid for itself twice over. The ordinary net results should be still more favorable, for the following reasons:

(1) At nurseries where acid or copper sulphate can be used without especially frequent watering the cost of the treatment will be less than at Halsey. At only one other nursery has it been found necessary to water the treated beds as much as at Halsey.

(2) The average increase in stand resulting from the treatment is much greater than the 20 per cent used in the preceding calculations. Figures based on exact counts for two or more seasons are available from five localities (Halsey, the Kansas sand hills, Garden City, Fort Bayard, and Monument). The average increase in stand resulting from the best treatments at all of these nurseries is exactly 100 per cent.

(3) An additional advantage, of greater value than the average increase in stand, is the stabilization of output through the prevention of damping-off epidemics.

(4) A further advantage is the development of more uniform stands in the beds by the prevention of damping-off patches.

(5) In addition to the advantages from increased stands and decreased damping-off, disinfectant treatment often has incidental results in the way of weed control or of increased growth of the conifers which may by themselves more than pay all costs connected with the treatment. These secondary advantages are discussed in the following paragraphs.

SECONDARY ADVANTAGES FROM DISINFECTANT TREATMENTS.

STIMULATION OF GERMINATION CAUSED BY DISINFECTANTS.

It is common and, in fact, almost invariable with all of the disinfectant treatments which have been successfully used to find a higher germination percentage in the treated plats than in the controls. In some cases this increase in germination (or, more accurately speaking, in the number of seedlings which appear above the soil surface) is very large. Whole groups of treated plats have in some cases given an apparent germination percentage three times that prevailing in the untreated plats in the same group. While such large increases are not common, it is a very frequent thing for the advantage in increased germination to be greater than that resulting from the control of damping-off after germination. (Compare the first and second columns under the head of "Relative results" in Tables I and II.) Such increases are mainly due to the control of parasites by the treatments; in the untreated plats *Pythium* and *Rhizoctonia* kill many seedlings or sprouting seeds before they break through the soil cover. However, in some cases at least, disinfectants, by direct action or by their effect on the soil, appear to cause seed to germinate which would otherwise have remained dormant. The advantage from this apparent stimulation of dormant seed can not be quanti-

tatively separated from the advantage due to the control of parasites. The sum of the results of the treatments in stimulating germination, protecting the germinating seed from parasites, and in preventing damping-off are all cumulatively expressed by the increase in final stand in the treated over the untreated plats at the end of the season.

INCREASED SIZE OF SEEDLINGS CAUSED BY DISINFECTANTS.

At three of the nurseries where experiments were conducted for several seasons it was found that there was a distinct increase in the size of pine seedlings as a result of treatment with sulphuric acid. Immediately after the seedlings come up, the only effect, when there is a noticeable effect, is a decreased growth rate in the acid plats. This effect later disappears, and during the latter part of the season the seedlings normally grow faster in the acid plats than in the controls or in plats treated with most other disinfectants. At the nursery at Halsey during 1912 and 1913, seedlings were measured in five experimental series, three of jack pine, one of western yellow pine, and one of Norway pine. The average of all five shows that the acid caused an increase in height of 37 per cent.

At the nurseries in the Kansas sand hills and at Garden City acid had a much more surprising effect. The results with western yellow pine indicated a moderate increase in the first season's growth, in agreement with the Halsey results, this increase being still distinctly noticeable, at least at the sand-hill nursery, at the end of the second year's growth. But with jack pine at these nurseries unexpectedly large increases were secured. At both nurseries jack pine ordinarily makes a slow growth during the first season. In plats sown in November, 1912, and treated with sulphuric acid early the following spring, the average height of jack pine after a year's growth was found to be more than three times that of the seedlings in the untreated plats. The effect of acid treatment on the seedlings at the Garden City nursery is shown in Plate II, figure 1. At the Kansas sand-hill nursery, root systems as well as tops were examined. The increase in root development appeared entirely commensurate with the increased size of the tops. The air-dry weight of the tops at the sand-hill nursery was $7\frac{1}{2}$ times as great in these acid plats as in the untreated plats.

It is not to be expected that the acid will result in increased growth of any species in all soils, as the effect on growth is apparently due not to direct stimulation of the conifers, but rather to the effect of the acid on the soil. It is interesting to note that the only great increases in growth have been found at the nurseries where the soil water contained the largest quantities of acid carbonates.

The economic value of a moderate increase in growth, such as is secured at Halsey, depends largely on the system of handling stock. If the seedlings are to be held in the seed bed for two years an increase

in the first season's growth is not very important. If, however, it is desired to transplant the stock at the end of the first season the increase in size due to acid, at least in the jack pine, which is ordinarily most helped, may mean the difference between success and failure. In a case of great increase in size, such as was secured by the acid treatment of jack pine at the two nurseries in Kansas, the economic results are more positive. It was entirely impossible to raise 1-year-old stock large enough to transplant without the use of acid. With the acid treatment 1-year-old seedlings were produced which appeared to be in every way the equal of untreated 2-year-old stock for transplanting purposes. The time and expense involved in holding the stock for a second year in the seed beds were avoided. At the Garden City nursery the advantage went even farther than that. The seedlings in the untreated beds were so small that they could not withstand winterkilling and were practically all killed before the second growing season. The seedlings in the acid plats immediately adjacent came through the winter practically without loss. While, as already stated, the acid proved ineffective at this nursery so far as the control of damping-off is concerned, on account of the carbonates present in the soil, its effect on growth and the resultant freedom from winter loss alone positively indicated its use on jack-pine beds in combination with the toxic salts found most valuable for damping-off control.

WEED CONTROL BY DISINFECTANTS.

At the nurseries where weeds are troublesome in the seed beds the effect of the disinfectants on the weeds is probably the most important of the secondary results of the treatment. The plants commonly occurring as weeds seem on the whole much more sensitive to acids and to copper and zinc salts than do the conifers. The result is that treatments so worked out as to be entirely harmless to the coniferous seedlings in the beds are found at a number of nurseries to keep the beds almost entirely free from weeds during the first three or four weeks after the germination of the conifers. This is just the time when most weeds can be expected to appear in the untreated beds and when the delicacy of the young conifers makes it difficult to do even hand weeding without breaking or pulling up many of the seedlings. The economic value of this weed-control feature varies with different nurseries. At some places the efficiency with which weeds are controlled is less than at others. At some places weeds are not numerous enough to make weed control a consideration of any very great importance. The only place at which an attempt has been made to reduce to a dollars-and-cents basis the value of the weed-controlling effect of a damping-off control treatment is at Halsey, Nebr. Approximate figures obtained from forest officers indicate that the entire cost of the hand weeding required during the seasons consid-

ered was approximately \$7.60 per 1,000 square feet; that for the season of 1912 the cost in the acid beds was \$5.40 less than in the untreated beds; and in 1913, \$5.20 less. This saving in cost of weeding exceeds the entire cost of the acid treatment as estimated during the first of these years. While the net value of weed control will not be as great as this in all seasons or at all nurseries, it appears that at several of the nurseries where tests have been carried on the benefit from weed control (Pl. II, fig. 2) or from increased growth of the seedlings, or from both of these effects combined, will be sufficient to more than justify the treatment. In such cases the control of damping-off secured by the treatments will be clear gain. It is especially interesting to note that in the seed beds of the Feather River Forest Experiment Station (California) a light sulphuric-acid treatment is in regular use simply on account of its value as a weed killer, entirely irrespective of any effect on damping-off.

CONCLUSIONS AS TO SOIL DISINFECTANTS.

The results listed in Table III indicate the complexity of the problem of soil treatment to control damping-off parasites. It is at once evident that a single season's experiments conducted on a single soil do not furnish a basis on which it is safe to make recommendations for general use. It furthermore appears that even after as extensive experiments as are here reported, it is not possible to prescribe any one treatment which will be safe and effective at all nurseries. Heat, the disinfecting agent most commonly employed by workers with truck soils, has proved inferior to other methods at all of the nurseries at which it has been tried. Sulphur, which is reported to have given excellent results against certain root diseases of other plants, has on the whole given disappointing results in pine seed beds. Formaldehyde, sulphuric acid, copper sulphate, and zinc chlorid, the four most generally satisfactory substances, have each failed at one or more nurseries. Especially at nurseries where no adequate watering system has been installed the frequent watering which beds treated with acid or with copper and zinc salts sometimes require means considerable trouble and expense.

However, after all these difficulties and drawbacks have been considered, analysis of the results indicates that it will be practicable to control damping-off by some soil treatment at any nursery where it is troublesome. The first part of Table III, containing results at the seven nurseries where repeated tests have been made, is, of course, the most important. At all of these nurseries soil treatment has proved successful. It is significant that at all but one of these seven sulphuric acid has proved successful. The acid failed at the seventh nursery only because of the high carbonate content of the soil, a condition rarely found at coniferous nurseries. At this seventh nursery

the cheap and simple copper-sulphate treatment proved entirely satisfactory, with the alternative of zinc chlorid in case the copper salt should ultimately prove in any way unsatisfactory. At four of the seven, all that appears necessary to be done is to apply the disinfectant, and thereafter let the beds take care of themselves. Although specially frequent watering is required during the germinating season by treated beds at the other three nurseries, the cost of this, as has been shown for Halsey, is not excessive, and the amount of extra watering required to protect the germinating seedlings at the remaining two nurseries is less than at Halsey.

At the localities considered in the last part of the table, where the tests have been mainly or entirely limited to a single season, some facts of interest have been developed, though at none of them have the best control methods been definitely determined. At Dundee and Cass Lake a sufficient number of independent series of tests were made to show without doubt that some one of the treatments which resulted well will be found satisfactory for regular use. At most of the other nurseries in this second division the tests have been preliminary in character and are only indicative. At 13 of the 14 localities listed in the second part of the table, the results of the tests indicated the value of one or more of the treatments tested. At 9 of these 13 the indications were that the disease could be controlled by a treatment which would not make necessary any special watering of the beds. At the one nursery where no results were obtained (Pocatello) sulphuric acid was the only substance tested under proper watering conditions, and its failure is easily explained by the presence of soil carbonates.

Considering separately the soil treatments employed, it appears that there are four reasonably promising disinfectants for use on coniferous seed beds. The writers have experimented with approximately 50 different substances, alone or in combination, in the treatment of seed beds, and these tests, in conjunction with the results of the writers and of others which are summarized in Table III, indicate that the most generally satisfactory substances for such use are sulphuric acid, copper sulphate, zinc chlorid, and formaldehyde, of which the acid is the most promising.

The use of sulphuric acid has been reported at 20 different localities. At 17 of these it has given indications of value. Its failure at Pocatello and Garden City is merely an indication that it will not succeed in the presence of large quantities of soil carbonates. At Glenview, Ill., the tests were very preliminary and therefore not sufficient to show that it was valueless. It has become established as a regular part of nursery practice at all nurseries where it has been repeatedly tested, with the exception noted of the one where the soil contained carbonates. At several nurseries in the

Middle West, where the acid in single-season tests did not give as good results as other substances, there is reason to believe that the results of the acid treatment will be much better in normal seasons. The acid has to recommend it, in addition to its effectiveness against damping-off, the elements of cheapness, efficiency in killing weeds, and in many places of causing an increased growth of the conifers.

Copper sulphate, tested at 11 different places, gave no indications of value at three of them and very doubtful indications at the fourth. At the others it gave more or less indication of value, reaching the stage of regular nursery use at one nursery and at two others giving better results than the acid in single-season tests. Copper-sulphate treatment costs about the same as treatment with acid and is nearly or quite as effective in killing weeds, but has not been observed to result in any marked increase in growth of the conifers.

Data as to the value of zinc chlorid were secured from ten nurseries. At one of these it failed. At three others the tests were very preliminary, and while value was indicated the extent of value was not determined. At four it indicated value, but to a less extent than other treatments used. At the remaining two it indicated sufficient value to rank as a successful treatment. At both of the nurseries where it has been given repeated tests it has proved as good as any other treatment. At both of these, however, it has not been shown to be decidedly better than cheaper treatments (copper sulphate at Garden City and sulphuric acid at Fort Bayard), and therefore is not likely to replace them in regular use. Like copper sulphate, it kills weeds in addition to decreasing damping-off and has not been observed to cause increased growth of the conifers. The relatively high cost of this disinfectant, approximately one-half cent per square foot on heavy soils for material alone, is a point against it. Both copper sulphate and zinc chlorid cause injury to pines on some soils where acid seems entirely harmless. This means that their use will at most places necessitate more watering during the germinating period than is necessary when acid is used.

Data as to the value of formaldehyde in controlling damping-off have been secured from 12 places. At two of these it has failed. At another it has indicated value; extent undetermined. At five others it has indicated less value than sulphuric acid, while at the four remaining places it has been reported as successful.¹ It also kills weeds, has little effect on the growth of pines, and has the advantage of never making necessary any extra watering in treated plats. The points against it, in addition to its inferior efficiency in controlling damping-off at many nurseries, are its high cost and its tendency to kill seed if applied at or near the time of sowing. It is

¹ At Dundee, formaldehyde alone was considered a failure, as the only successful formaldehyde plats were those also treated with zinc chlorid.

necessary to treat beds some time before sowing, this period varying from two days to two weeks in different soils. The generally prescribed practice of covering the beds to prevent reinfection or premature evaporation of the formaldehyde during this period is troublesome and expensive. Further tests may prove it unnecessary.

In considering disinfectants, the ultimate as well as the immediate results should be taken into account. No data are at hand to show the effects of repeated treatments of soil with toxic salts or formaldehyde. The effects of single treatments seem to be purely temporary. Treatments of one-eighth and three-sixteenths ounce of copper sulphate per square foot (equivalent to 341 and 511 pounds per acre, respectively), which are expected to be quite sufficient for use against damping-off at most nurseries, involve additions of only one-sixth and one-fourth, respectively, of the amount which has been used in single treatments at Garden City without any noticeable permanent effect. Sulphuric acid might ultimately bring about an acid condition of the soil if used repeatedly, but this could be easily remedied at any time by the addition of lime. The only possible bad effect of continued use of the acid would therefore be an accumulation of sulphates. The sulphur added in a treatment of three-sixteenths fluid ounce of acid per square foot would be, roughly, 300 pounds per acre. If repeated every year, this would, of course, mean a considerable change in sulphur content. However, it would be a very rare thing for a treatment to be applied two consecutive years on the same soil, and where rotation is practiced five or six years commonly elapse between the growing of two crops of seedlings of susceptible species on the same soil. This minimizes the likelihood of any bad cumulative effect by the treatments.

The comparison of the four disinfectants considered in the foregoing paragraphs does not make possible a final statement as to their relative value. At most of the localities listed in Table III there have not been enough tests to give conclusive results. It is believed from the somewhat incomplete evidence secured that at most nurseries soil treatment with sulphuric acid will be found a satisfactory and probably the most satisfactory means of decreasing damping-off and that where it is not satisfactory success can be secured with some one of the other disinfectants—copper sulphate, zinc chlorid, or formaldehyde.

It is, of course, recognized that the treatments so far devised are not as simple and effective as are desired. Further tests of these disinfectants and of numerous others are under way. The problem of damping-off control is also being attacked from other directions than that of simple soil disinfection. It is hoped that a single disinfection method may be found which can be used on any soil and which will not require any unusual precautions against chemical injury; or, failing this, that some less direct procedure against the parasites

will be found satisfactory. The securing of final results along these lines will of necessity require several years' experimenting, because of the differences between different soils and the number of species of parasites and of conifers which have to be considered. Meantime, the foregoing results are published to enable nurserymen to make use of the experience already gained. Under the following heading are outlined a number of treatments, at least one of which should be found successful and profitable at any coniferous nursery where damping-off is prevalent.

SOIL TREATMENTS RECOMMENDED.

No treatments can be guaranteed as either safe or effective on all soils. However, it is nearly certain that for any nursery at least one of the following will be found successful. It is therefore recommended that any nurseryman who has serious losses from damping-off test some of these treatments on a small scale until he finds which one is best suited to his conditions. At least two successful tests should be made before a treatment is judged safe for large-scale use.

Treatments for heavy soils.

1. Sulphuric acid, three-sixteenths fluid ounce per square foot of bed, dissolved in from 1 to 2 pints of water per square foot of bed and applied immediately after the seed is sown and covered.

2. Same as treatment 1, but use one-fourth ounce acid per square foot.

3. Copper sulphate, one-eighth avoirdupois ounce per square foot, dissolved in water and applied immediately after the seed is sown and covered.

4. Same as treatment 3, but use three-sixteenths ounce per square foot.

5. Zinc chlorid, one-half ounce per square foot, dissolved in water and applied immediately after the seed is sown and covered.

6. Formaldehyde, one-half fluid ounce per square foot, dissolved in water and applied 10 days before the seed is sown. Keep the bed covered with paper, tarpaulin, or tight shade frames during these 10 days. Do not spade up formaldehyde beds after treatment. If necessary to cover the seed with soil from outside of the plat, which has not been treated, use subsoil just dug up from at least 1 foot below the surface.

7. Same as treatment 6, but apply the treatment only three days before sowing and do not cover with paper.

8. Air-slaked lime, one-half avoirdupois ounce per square foot, applied dry and raked into upper 3 inches of soil just before sowing. (If hydrated lime is used, three-eighths ounce per square foot will be sufficient.) Immediately after seed is sown and covered apply three-tenths ounce of sulphuric acid per square foot, dissolved in water.

9. Same as treatment 3, but use one-fourth ounce per square foot.

In dissolving disinfectants, use sufficient water to make from 1 to 2 pints of solution per square foot. Two pints should be used if the soil is dry; 1 pint is sufficient when the soil is wet.

Treatments for sandy soils.

1. Sulphuric acid, one-eighth fluid ounce per square foot, dissolved in water and applied immediately after the seed is sown and covered.

2. Same as treatment 1, but three-sixteenths ounce per square foot.

3. Copper sulphate, one-tenth avoirdupois ounce per square foot, dissolved in water and applied immediately after the seed is sown and covered.
4. Same as treatment 3, but one-sixth ounce per square foot.
5. Zinc chlorid, five-sixteenths avoirdupois ounce per square foot, dissolved in water and applied immediately after the seed is sown and covered.
6. Formaldehyde, five-sixteenths fluid ounce per square foot, dissolved in water and applied 10 days before seed is sown. Keep the bed covered with paper or tarpaulin during these 10 days. Do not spade up formaldehyde beds after treatment. If necessary to cover the seed with soil from outside of the plat, use subsoil just dug up from at least 1 foot below the surface.
7. Same as treatment 6, but apply only three days before seed sowing and do not cover beds with paper.
8. Air-slaked lime, three-eighths avoirdupois ounce per square foot, applied dry and raked into the upper 3 inches of soil just before sowing. (If hydrated lime is used, three-tenths ounce per square foot will be sufficient.) Immediately after the seed is sown and covered, apply one-fifth ounce of sulphuric acid per square foot, dissolved in water.

In dissolving disinfectants for sandy soils, use sufficient water to make from 1 to $1\frac{1}{2}$ pints of solution per square foot. One and one-half pints should be used if the soil is dry; 1 pint is sufficient if the soil is already wet.

GENERAL DIRECTIONS FOR TREATMENTS.

Commercial or technical grades of all the disinfectants are satisfactory. The sulphuric acid purchased should be concentrated, having a specific gravity of at least 1.82, while the formaldehyde solution, or "formalin" as it is sometimes called, should be the strongest obtainable, so-called 40 per cent solution, containing 37 per cent by weight. All disinfectants should be kept from the air as much as possible, as they change in strength if exposed. Copper sulphate requires the least care in this respect. *Acid should be dissolved by pouring it into the water—never by the reverse process.* Copper sulphate is quickest dissolved by putting it in a burlap sack and hanging it in the water just below the surface. Both of these solutions are corrosive to metal and should be handled only in wooden or earthenware containers and applied with sprinklers which have been coated inside with hot paraffin.¹ Acid is also hard on the hands and clothes. Men who use it on a large scale are very careful to keep their shoes heavily greased. Canvas gloves treated with hot paraffin or with a mixture of paraffin and a lighter grease, such as vaseline or lard, should be a valuable protection for the hands. The charring of wooden containers used in making up dilute acid solutions probably can be largely prevented by washing them out well with water containing washing soda before they

¹ To coat a sprinkler with paraffin, get the cake paraffin sold by grocerymen for use in sealing jelly and preserves. Shave off some of the paraffin into the sprinkler, and heat the sprinkler till all the paraffin is melted. Then turn the sprinkler around so that the liquid paraffin runs over the entire inside surface and finally pour what is left of the paraffin out through the spout. The whole can should be hot during the process, so that the paraffin will leave a thin coating; a thick coating cracks off too easily. The holes in the sprinkler head will have to be cleaned out with a pin or toothpick after the paraffin has hardened.

are put away at the close of work. A coating of linseed oil, very thoroughly dried, should also prevent the charring of wood. Acid which gets on the hands does no harm if washed off at once with water. In applying treatments on a large scale the sprinklers used should have the holes in the rose or sprinkler head enlarged, to permit faster work.

In trying out the treatments in the foregoing lists, Nos. 1 and 2, the most promising, should be tested first. If both fail, the other treatments should be tried. If the acid solutions cause the soil to effervesce, some of the other treatments should be tried at once, as on such a soil the acid is likely to fail.

The treatments should be applied to small plats which are intermingled with untreated plats for comparison. For test plats, 3 by 4 feet has been found a convenient size. Good results can be obtained with even smaller areas than this, but all plats should be at least 2 feet wide. An arrangement of plats which the writers have found satisfactory is shown in figure 1. The seed for each plat, treated and untreated, should be measured out separately, so that all plats will get equal quantities of seed. Then the number of seedlings living on each plat at the end of the season will show which treatment is most valuable. In watering, shading, and in every other way treated plats should be handled just like the untreated beds, to make the test a fair one.

As soon as the seedlings begin to drop their seed coats, plats treated with acid, copper sulphate, or zinc chlorid should be examined for chemical injury to the roots of the seedlings.¹ If such chemical injury is found to occur, two courses will be open: (1) To test the same treatment again, watering the treated plats thoroughly every day from sowing till germination is complete; or, (2) to abandon the treatment which caused injury and try to get sufficient control of the disease by a weaker treatment or by another disinfectant.

Treatments 6, 7, and 8 are inserted especially for use at places where acid causes injury and where frequent watering is not practicable; they are reasonably certain not to cause injury to seedlings under any circumstances.

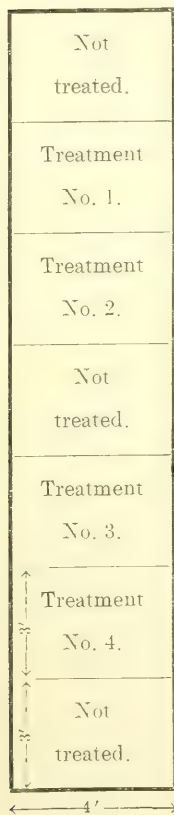


FIG. 1.—Suggested arrangement of test plats.

¹ The method of detecting chemical injury and illustrations of injured and uninjured seedlings have been given in a previous publication: Hartley, Carl. Injury by disinfectants to seeds and roots in sandy soils. U. S. Dept. Agr. Bul. 169, p. 9, pl. 1. 1915. This bulletin can be obtained by sending 5 cents in coin to the Superintendent of Documents, Government Printing Office, Washington, D. C.

SUMMARY.

(1) By damping-off is meant the killing of very young seedlings by parasitic fungi. It is the most serious difficulty encountered in raising coniferous seedlings.

(2) To decrease losses from the disease excessive moisture and shade should be avoided. Caution must be used in following this recommendation or many seedlings may be killed by drought or by white-spot injury to the base of the stem. Damping-off can often be decreased by putting beds on very sandy soil. Seed should not be sown any thicker than necessary. It appears better to sow broadcast than in drills. Late fall sowing results in decreased losses at some nurseries and is worth trial. Proper attention to all of these measures will decrease the losses from damping-off, but at most nurseries they are not sufficient really to control the disease.

(3) The addition of lime, wood ashes, and in some cases nitrogenous fertilizers seems to increase damping-off. Soil alkalinity appears to favor the disease. No effect has been noted from green manures. The use of unrotted stable manure has had very bad results; properly rotted manures seem less objectionable. Tankage, charcoal, and cane sugar are the only nondisinfecant substances which to date have given any hope of disease control.

(4) Soil disinfection has so far proved the best method of combating damping-off. Of many methods tested, treatments with sulphuric acid, copper sulphate, zinc chlorid, and formaldehyde have proved the most satisfactory. The disinfectants behave quite differently at different nurseries. The results of treatments at many different localities are summarized in Table III. The acid has on the whole given the best results. Heat disinfection has been only partly effective. Disinfection by acid or copper sulphate is cheaper than by the other methods commonly recommended.

(5) In addition to decreasing damping-off after the seedlings come up, the chemical disinfectants above mentioned, when properly used, cause an increase in the apparent germination and are very helpful in controlling weeds. This latter effect alone at some nurseries pays the entire expense of the treatment. Sulphuric acid has, furthermore, at some places resulted in marked increases in the late-season growth of pines. (See Pl. II.)

(6) In some soils formaldehyde kills dormant seed, and the other three most satisfactory disinfectants at some nurseries kill the root tips of germinating seedlings. By proper precaution, all such injury may be prevented.

(7) The results obtained to date show that it is entirely possible and practicable to control damping-off by soil disinfection. Unfortunately, the varying behavior of disinfectants at different places

renders it impossible to recommend any single treatment which will be everywhere successful. Directions are given for simple tests, by which it is believed that any nurseryman can develop a treatment that will succeed under his conditions.

(8) Further experiments are being conducted, with the hope of discovering either a more generally applicable disinfectant method than any of those so far tested or else a means of controlling the disease without the use of disinfectants.

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THE EFFECT OF CULTURAL AND CLIMATIC CONDITIONS ON THE YIELD AND QUALITY OF PEPPERMINT OIL.

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INTRODUCTION.

The peppermint plant, known botanically as *Mentha piperita* L., is cultivated extensively both in the United States and foreign countries as the source of a volatile oil which is widely used as a flavoring and therapeutic agent. The value of the oil depends much upon its composition. The principal ester constituent, menthyl acetate, possesses a very fragrant minty odor, to which the agreeable aroma of the oil is largely due. The alcoholic constituent, menthol, possesses the well-known penetrating minty odor and characteristic cooling taste. The flavoring properties of the oil are due largely to both the ester and alcoholic constituents, while the medicinal value is attributed to the latter only. The elaboration of these constituents depends upon the various cultural and climatic conditions to which the plant is subjected during growth.

In order to obtain data bearing on possible variations in the composition of peppermint oil under varying conditions, plants were grown under various conditions of soil and climate and were harvested at various stages of growth. The oil was distilled from certain parts and also from the entire herb in both the fresh and the dry condition and was then subjected to thorough examination.

EFFECT OF SOIL AND CLIMATE ON THE COMPOSITION OF PEPPERMINT OIL.

Henderson states ¹ that peppermint plants grown on a river bank on heavy loam and on deep sandy loam yielded oils which showed distinct differences in composition. According to Umney,² soil and climatic conditions are responsible for the higher content of esters in some peppermint oils than in others. Charabot and Hébert ³ have shown that the formation of certain constituents of the oil, and especially the esters, is favored by treating the soil with sodium chlorid and sodium nitrate. Mossler ⁴ has also observed that certain fertilizers, such as saltpeter, superphosphate, and potash, tend to favor the growth of the plant and the production of oil therein.

In order to study the effect of various types of soil and climatic conditions upon the general composition of peppermint oil, plants were grown at Webster, S. Dak., on rich black loam soil; at Glenn Dale, Md., on light sandy soil; and at Arlington Farm, Va., on heavy clay soil. The yields of oil distilled from these plants and also the physical and chemical properties were determined, and the results are given in Table I.

Only very slight differences are noted in the yield of oils obtained from the plants grown on the different soils. The physical properties—color, odor, and taste—likewise show only slight variations. The specific gravity of the Arlington oils distilled during two seasons are lower than the South Dakota or Maryland oils. The rotation and refraction of the various oils differ considerably. The Arlington oils are slightly more soluble in 80 per cent alcohol than either of the other oils.

Comparing the chemical composition of oil distilled from the plants grown at Arlington with that from the South Dakota plants, it will be seen that the latter is richer in both esters and total menthol, while the ester content of the oil from Maryland plants is much greater than in either of the other oils.

From these results and from results obtained by other observers it may be inferred that light soils of either a sandy or loamy nature are more conducive to the production of esters and menthol in the oil than soils of heavy texture. In the case of the oils first compared it is probable that the climatic conditions during the growing period acted jointly with the soil conditions to bring about the difference in the oils. This relation, however, did not apply to the oils produced

¹ Henderson, H. J. An experiment in peppermint culture. *In Pharm. Jour.*, v. 87 (n. s., v. 33), no. 2493, p. 175-176. 1911.

² Umney, J. C. The effects of climate and soils on oils of peppermint. *In Pharm. Jour.*, v. 57 (s. 4, v. 3), no. 1362, p. 103-104. 1896.

³ Charabot, Eugène, and Hébert, Alex. Influence de la nature de milieu extérieur sur l'état d'hydratation de la plante. *In Compt. Rend. Acad. Sci. [Paris]*, t. 136, no. 3, p. 160-163. 1903.

⁴ Mossler, Gustave. Ueber den Einfluss verschiedener Kulturbedingungen auf das ätherische Oel von *Mentha piperita*. *In Pharm. Post*, Jahrg. 45, no. 1, p. 2-5. 1912.

from the plants grown at Glenn Dale, Md., and Arlington Farm, Va., since these are but a few miles apart and the general climatic conditions are practically the same in both localities.

TABLE I.—*Comparison of yields and physical composition of peppermint oils distilled from plants grown in several localities on various types of soils.*

Locality and soil.	Yield of oil.	Physical properties.					Chemical composition (per cent).			
		Color, odor, and taste.	Specific gravity.	Rotation, 50 mm. tube.	Refraction.	Solubility in 80 per cent alcohol.	Free acid (as acetic).	Free esters (menthyl acetate).	Menthol.	
									Free.	Total.
Arlington Farm, Va. (heavy clay soil).	P. ct. 0.12	Pale yellow; agreeable menthol-like odor.	a 0.9203	— 10.6	b 1.4662	Volumes. c 1.2	0.21	7.07	46.5	51.7
Do.....	.13	Pale yellow; mild, agreeable, minty odor; fatty, cooling, pungent taste.	a. 9273	— 5.7	a 1.4820	d .6	.03	11.67	30.94	40.13
Webster, S. Dak. (rich black loam).	.10	Pale straw; pleasant flowery odor; pungent, minty, cooling taste.	a. 9280	— 8	b 1.4715	d 1.5	.05	9.9	46.48	54.28
Glenn Dale, Md. (light sandy soil).	.11	Pale yellow; agreeable aromatic, minty odor; bitter, slightly pungent, cooling taste.	a. 9403	— 10	e 1.4735	d .8	.75	23.34	35.89	54.28

a At 22° C.

b At 25° C.

c Turbid in 2 volumes or more.

d Turbid in 2½ volumes or more.

e At 23° C.

YIELD OF OIL FROM FRESH AND FROM DRY PLANTS AT VARIOUS STAGES OF GROWTH.

In order to study the effect of the time of harvest upon the yield and quality of peppermint oil and also the yield of oil as obtained from fresh and dry plants, experiments were conducted through a series of years, from 1908 to 1912, inclusive. The plants were harvested at three distinct stages of growth, namely, the budding, flowering, and fruiting stages, and the oil was distilled from both the fresh and the dried plants. A comparison was made of the various oils, the results being shown in Table II.

The yield of oils distilled from the fresh plants during the budding stage shows considerable variation, the yield in 1908 being especially high. During 1909, 1910, 1911, and 1912 considerably less variation is observed. Similar deviation during the flowering stage is to be noted, the yield in 1908 again being noticeably higher. More uniformity is apparent in the results obtained from the fruiting plant. In two of the seasons mentioned (1909 and 1911) the yield of oil during the fruiting stage was slightly in excess of that from either the budding or the flowering stage.

TABLE II.—*Yield of peppermint oil from the fresh and from the dry herb at various dates of distillation and stages of growth during five successive years.*

[All yields of oil calculated on the basis of fresh herb.]

Description of material.	1908		1909		1910		1911		1912		Average.
	Date.	Yield.	Date.	Yield.	Date.	Yield.	Date.	Yield.	Date.	Yield.	
Fresh herb:		<i>P. ct.</i>		<i>P. ct.</i>		<i>P. ct.</i>		<i>P. ct.</i>		<i>P. ct.</i>	<i>P. ct.</i>
Budding...	July 22	0.23	July 14	0.13	July 28	0.10	July 17	0.12	Aug. 5	0.09	0.134
Flowering...	Aug. 21	.20	July 24	.12	Aug. 16	.13	Aug. 17	.09	Sept. 21	.12	.132
Fruiting...	Sept. 25	.10	Aug. 10	.17	Sept. 16	.10	Sept. 18	.13	Oct. 5	.07	.114
Dry herb:											
Budding.....			July 19	.080	Aug. 5	.070	Aug. 15	.050			.066
Flowering.....			July 26	.042	Sept. 8	.022	Sept. 11	.088			.050
Fruiting.....			Aug. 19	.052	Sept. 27	.048	Oct. 2	.040			.046

The average percentage of moisture in the budding, flowering, and fruiting plants during the years 1909, 1910, and 1911 was 78.2, 74.2, and 69 per cent, respectively. The yield of oils obtained from the dried plants is lower in every case than from the fresh material. The general average yield is approximately 50 per cent lower than the yield obtained from the fresh herb at the same stage of growth. It appears, therefore, that prolonged drying of the herb before distillation is decidedly detrimental to the yield of oil obtainable.

In an experiment to determine what effect drying the plant has on the yield and constants of the oil, Todd¹ states that no loss of oil results when the plant is dried before distillation and that the color and solubility of the oil from the dried plants are superior to those from the fresh plants. The specific gravity, however, is slightly higher.

From the general averages during the three successive stages of growth of the plants, it appears that the yield of oil tends to decrease as the plant matures.

Information regarding the distribution of the oil in the plant was obtained by distilling separately the leaves and the tops of the plants at the three successive stages of growth and comparing these results with those recorded for the whole fresh herb. The results of these experiments are shown in Table III.

TABLE III.—*Comparison of yields of peppermint oil from the fresh leaves, from the tops, and from the whole fresh herb at different stages of growth during three successive years.*

Parts of plant and stage of growth.	Yield of oil (per cent).			
	1909	1910	1911	Average.
Whole herb:				
Budding.....	0.13	0.10	0.12	0.116
Flowering.....	.12	.13	.09	.113
Fruiting.....	.17	.10	.13	.133
Leaves:				
Budding.....	.20	.15	.26	.203
Flowering.....	.27	.25	.39	.303
Fruiting.....	.13	.08	.15	.120
Tops:				
Budding.....	.20	.10	.22	.173
Flowering.....	.16	.12	.42	.233
Fruiting.....	.19	.08	.19	.153

¹ Todd, A. M. An experiment with peppermint plants. *In Amer. Drug.*, v. 15, no. 9, p. 161. 1886.

The results show that the yield of oil from the whole herb in the budding and flowering stages is consistently lower than that from the leaves and tops. In the fruiting stage, however, a slight deviation is observed. The yield of oil from the fresh herb is slightly higher in some instances than that from the leaves and tops. In practically all cases, however, the average yield from the leaves and tops during the three successive years is higher than the average from the whole herb at the three stages of growth.

From these results it is concluded that the largest portion of the oil in the peppermint plant is found in the leaves. The flowering tops contain slightly less than the leaves, and the stems are nearly devoid of oil. This latter fact possibly accounts for the lower percentage of oil in the whole plant as compared with that from the leaves and tops.

PHYSICAL AND CHEMICAL PROPERTIES OF PEPPERMINT OIL FROM FRESH AND FROM DRY PLANTS AT VARIOUS STAGES OF GROWTH.

In order to make possible a comparison of the properties of the various oils, a careful physical and chemical examination was made, and the results are presented in Table IV.

TABLE IV.—*Physical properties and chemical composition of peppermint oil distilled from the fresh and from the dry herb at various stages of growth during successive years.*

Year and description of material.	Physical properties.					Chemical composition (per cent).			
	Color, odor, and taste.	Specific gravity.	Rotation, 50 mm. tube.	Refraction.	Solubility in 80 per cent alcohol.	Free acid (as acetic).	Ester (menthyl acetate).	Menthol.	
								Free.	Total.
1908.									
Fresh herb:									
Budding.....	Pale yellow; pleasant menthol-like odor; cooling taste.	d. 912	— 15.8	b1.4696	Volumes. c 1.5	0	9.55	30.56	38.08
Flowering.....	Pale yellowish green; pleasant esterlike odor; very pungent taste.	d. 924	— 4.5	b1.4728	c 1.25	0	14.50	23.97	35.39
Fruiting.....	Yellowish green; pleasant minty odor; less pungent and cooling taste.	d. 918	— 21	b1.4681	c 1.5	0	24.40	34.33	53.55
1909.									
Fresh herb:									
Budding.....	Golden yellow; pleasant, faint odor; slightly pungent and cooling taste.	d. 9158	— 9.2	e1.4738	f 1	.10	6.72	30.1	35.39
Flowering.....	Pale yellow; agreeable menthol-like odor; pungent, minty taste.	d. 9203	— 10.6	e1.4662	g 1.2	.21	7.07	46.5	52.09
Fruiting.....	Straw colored; very flowery odor; minty, pungent, taste.	d. 9151	— 8.3	e1.4676	h. 8	.10	12.37	33.8	43.58

a At 23° C.

b At 24° C.

c Clear solution.

d At 22° C.

e At 25° C.

f Clear in excess.

g Turbid in 2 volumes or more.

h Turbid in 1½ volumes or more.

TABLE IV.—*Physical properties and chemical composition of peppermint oil distilled from the fresh and from the dry herb at various stages of growth during successive years—Continued.*

Year and description of material.	Physical properties.					Chemical composition (per cent).			
	Color, odor, and taste.	Specific gravity.	Rotation, 50 mm. tube.	Refraction.	Solubility in 80 per cent alcohol.	Free acid (as acetic).	Ester (menthyl acetate).	Menthol.	
								Free.	Total
1909.									
Dry herb:					Volumes.				
Budding.....	Greenish yellow; strong minty odor; pungent, minty taste.	<i>a</i> 0.9337	—13.1	<i>b</i> 1.4695	<i>c</i> 1.2	0.17	13.26	36.07	46.38
Flowering.....	Golden yellow; minty odor; pungent, minty, slightly fatty taste.	<i>a</i> .9163	—13.5	<i>b</i> 1.4695	(<i>d</i>)	.16	12.73	37.37	47.44
Fruiting.....	Yellow; unpleasant minty odor; strong, pungent, minty taste.	<i>a</i> .9344	— 8.1	<i>b</i> 1.4718	<i>e</i> 1	.36	17.68	34.2	48.15
1910.									
Fresh herb:									
Budding.....	Dark golden; not fragrant, minty odor; slightly bitter, pungent, minty taste.	<i>f</i> .9155	—12.1	<i>a</i> 1.4718	<i>g</i> .7	.86	16.62	43.76	56.85
Flowering.....	Pale yellow; mild, agreeable odor; fatty, strong, cooling, pungent taste.	<i>f</i> .9273	— 5.7	<i>a</i> 1.4820	<i>e</i> .6	.03	11.67	30.94	40.13
Fruiting.....	Yellowish green; very fragrant flowery odor; very bitter and slightly pungent taste.	<i>f</i> .9250	— 7	<i>a</i> 1.4712	<i>h</i> .8	1.14	20.86	12.7	29.14
Dry herb:									
Budding.....	Light golden; herb-like, faint, minty odor; slightly bitter, pungent, minty taste.	<i>f</i> .9167	—11	<i>a</i> 1.4724	<i>h</i> .6	1.20	19.80	39.41	55.01
Flowering.....	Pale brown; herb-like odor; pungent and cooling taste.	.....	.....	<i>a</i> 1.4765	.....	3.20	30.41	.....	.....
Fruiting.....	Golden yellow; fragrant, pleasant odor; very bitter and slightly pungent taste.	<i>f</i> .9383	— 3.3	<i>a</i> 1.4713	<i>i</i> .5	.56	20.51	.....	.....
1911.									
Fresh herb:									
Budding.....	.....	.....	.....	.....	.....	.06	12.02	32.37	41.84
Flowering.....	.....	.....	.....	.....	.....	.20	13.79	34.11	44.97

a At 22° C.

b At 25° C.

c Turbid in excess.

d Turbid in 1 volume absolute alcohol; insoluble in 80 and 90 per cent alcohol in any proportion.

e Turbid in 2 volumes or more.

f At 24° C.

g Turbid in 4 volumes or more.

h Turbid in 1½ volumes or more.

i Turbid in 1¼ volumes or more.

Table IV shows that the oils distilled from the fresh herb collected at the three stages of growth show only slight differences in their general properties—color, odor, and taste. The oils from the flowering plants show a higher specific gravity and comparatively lower rotation than those from the budding and fruiting stages. With respect to their solubility in 80 per cent alcohol the several oils vary considerably.

From these physical properties it may be concluded that in several instances there are material differences in the composition of the oils, since the physical properties are greatly influenced by the constituents of the oils.

The color of the oils from the dry herb is uniformly darker than that of the oils from the fresh herb and the odor is distinctly less agreeable. The specific gravity is noticeably higher than in the oils from the fresh herb, but the variations in refraction, rotation, and solubility are less striking. Conspicuous among the oils from the dry herb is that from the flowering plants in 1909. This oil was insoluble in any proportion of either 80 or 90 per cent alcohol.

Table IV also shows that the percentage of free acids, calculated as acetic acid, in the various oils from the fresh plant varies considerably, probably as a result of the breaking down of the ester of the oil into free acid and menthol or of the inhibition of the esterification of the acid and menthol with the formation of menthyl acetate.

On comparing the percentage of ester or menthyl acetate in the oils from the fresh herb during the three stages of growth, it will be observed that the proportion of this constituent increases as the plant develops. The oil obtained at the fruiting stage is in every case richer in esters than the oil from the flowering or budding plants. The content of menthyl acetate of the oils varies in the budding plant during the several seasons from 6.72 to 16.62 per cent, in the flowering plant from 7.07 to 14.5 per cent, and in the fruiting plant from 12.37 to 20.86 per cent.

The free menthol content of the oils does not show the same tendency to increase as is noted in the case of the ester content. A certain relationship, however, seems to exist between the ester content and that of free menthol, since in many cases when the ester content is high the free menthol content is low, and vice versa. The oil distilled from the fruiting plant in 1910, in which year the percentage of esters was the highest, has the lowest percentage of free menthol, while the oil from the flowering plant in 1909, which contained a low percentage of esters, possessed the highest percentage of free menthol. This, however, is not true in every instance. That a relationship of this kind should exist between the ester content and the free menthol content is but natural, as the higher the percentage of menthol in combination in ester form the lower is the percentage of free menthol.

The percentage of total menthol represents the combined content of free menthol and the menthol held in combination in the form of the ester. Therefore, the oils with the highest content of total menthol are those which contain the highest content of free menthol and also combined menthol, or ester. This is strikingly shown in

the oil from the fruiting plant in 1908, which contains 53.55 per cent of total menthol, and in the oils from the flowering plant in 1909 and the budding plant in 1910, which contain, respectively, 52.09 and 56.85 per cent of total menthol.

In comparing the oils from the dry herb with those from the fresh herb it will readily be observed that the content of free acetic acid is uniformly higher in the oil from the dry plants. It is interesting to note that in practically every instance the ester content is also higher than in the oils from the fresh plants. It would appear, therefore, that during the drying process there occurs a chemical change which is favorable to esterification. Notwithstanding the higher content of esters, the odor of the oils was decidedly inferior. This is attributed to the presence of certain volatile substances formed during drying, which distilled over with the oils and imparted an objectionable herby odor to them.

The free menthol and the total menthol content of the various oils from both the dry and the fresh plants appears to be similarly affected, as the percentage of both free and total menthol is uniformly high. It is, however, doubtful whether the increased content of ester and menthol in the dry plants would warrant the drying of the plants before distillation, since, as previously noted, a considerable percentage of oil is lost when the plants are dried.

The distillation of peppermint oil from plants in a fresh condition at different periods of growth up to the time of flowering has been reported by Charabot,¹ who finds that the density and rotation diminish during vegetation. The plant is richest in menthol at the appearance of vegetation and lowest in the combined menthol, or esters. As the growth of the plant progresses, the percentage of the combined menthol, or esters, increases.

A study was made of the physical and chemical properties of the oils distilled separately from the fresh leaves and flowering tops, and for comparison the results are presented with those obtained for the oils from the whole fresh herb, as shown in Table V.

The general characters of the oils from the leaves and tops at the successive stages of growth are very similar to those of the oils from the entire herb. The specific gravity and rotation of the oils from the leaves and the tops are higher in nearly every case than the same constants of the oils from the entire herb. The refractive indexes are variable, while the solubility in 80 per cent alcohol is less in most cases than that of the oils from the whole herb. These constant differences in specific gravity, rotation, and solubility apparently denote a difference in the composition of the oils from the leaves and tops as compared with that from the whole herb.

¹ Charabot, Eugène. Recherches sur les migrations et les métamorphoses des composés terpéniques dans la menthe poivrée. *In* Bul. Soc. Chim. Paris, s. 3, t. 23, p. 466-474. 1900.

TABLE V.—Comparison of the physical properties and the chemical composition of peppermint oils distilled from the fresh leaves, from the tops, and from the entire fresh herb at the various stages of growth.

Year and description of material.	Physical properties.					Chemical composition (per cent).			
	Color, odor, and taste.	Specific gravity.	Rotation, 50 mm. tube.	Refraction.	Solubility in 80 per cent alcohol.	Free acid (as acetic).	Ester (menthyl acetate).	Menthol.	
								Free.	Total.
1909.									
Budding stage:					Volumes.				
Herb.....	Golden yellow; pleasant, faint odor; slightly pungent, cooling taste.	a 0.9158	— 9.2	b 1.4738	c 1	0.10	6.72	30.1	35.39
Leaves.....	Straw colored; fragrant but faint minty odor; fatty, pungent, slightly bitter taste.	a. 9143	—12.1	b 1.4713	d 1.4	.014	9.9	37.7	45.67
Tops.....	Straw colored; very fragrant minty odor; fatty, bitter, pungent taste.	a. 9151	—12	b 1.4718	e 1	.116	8.84	31.8	38.76
Flowering stage:									
Herb.....	Pale yellow; agreeable menthol-like odor; pungent, minty taste.	a. 9203	—10.6	b 1.4662	f 1.2	.21	7.07	46.5	52.09
Leaves.....	Straw colored; pleasant, minty odor; pungent taste.	a. 9389	—11	b 1.4706	f 1.2	.52	17.3	41.7	55.38
Tops.....	Straw colored; flowery odor; pungent taste.	a. 9370	—10.3	b 1.4732	f 1	.48	15.9	37.75	50.29
Fruiting stage:									
Herb.....	Straw colored; very flowery odor; minty, pungent taste.	a. 9151	— 8.3	b 1.4676	e. 8	.10	12.37	33.8	43.58
Leaves.....	Golden yellow; pleasant, minty odor; minty, pungent taste.	a. 9373	— 9.6	b 1.4730	d 1.5	.32	19.8	37.58	53.18
Tops.....	Light straw colored; pleasant, flowery odor; minty, slightly pungent taste.	a. 9223	— 9.5	b 1.4723	e 1	.16	15.56	34.8	47.08
1910.									
Budding stage:									
Herb.....	Dark golden; not fragrant, minty odor; slightly bitter, pungent, minty taste.	g. 9155	—12.1	a 1.4718	h. 7	.86	16.62	43.76	56.85
Leaves.....	Golden yellow; faint, not especially minty odor; slightly bitter, pungent taste.	g. 9156	—13.1	a 1.4710	h. 6	.90	19.80	18.79	34.39
Tops.....	Golden yellow; agreeable, minty odor; strong, pungent, bitter, cooling taste.	.....	.....	.....	.....	.13	13.44	29.19	39.78
Flowering stage:									
Herb.....	Pale yellow; mild, agreeable odor; fatty, strong, cooling, pungent taste	g. 9273	— 5.7	a 1.4820	d. 66	.03	11.67	30.94	40.13

a At 22° C.

b At 25° C.

c Clear in excess.

d Turbid in 3 volumes or more.

e Turbid in 1½ volumes or more.

f Turbid in 2 volumes or more.

g At 24° C.

h Turbid in 4 volumes or more.

TABLE V.—*Comparison of the physical properties and the chemical composition of peppermint oils distilled from the fresh leaves, from the tops, and from the entire fresh herb at the various stages of growth—Continued.*

Year and description of material.	Physical properties.					Chemical composition (per cent).			
	Color, odor, and taste.	Specific gravity.	Rotation, 50 mm. tube.	Refraction.	Solubility in 80 per cent alcohol.	Free acid (as acetic).	Ester (menthyl acetate).	Menthol.	
								Free.	Total.
1910.									
Flowering stage—Continued.									
Leaves.....	Pale yellow; strong minty odor; slightly fatty, bitter, pungent, cooling taste.	a 0.9231	—9.4	b 1.4753	Volumes. c 0.7	1.90	22.27	37.83	55.38
Tops.....	Pale yellow; fragrant, agreeable odor; fatty, bitter, pungent, cooling taste.	a. 9242	—6.5	b 1.4780	c. 8	1.43	22.98	48.60	66.71
Fruiting stage:									
Herb.....	Yellowish green; very fragrant flowery odor; very bitter, slightly pungent taste.	a. 9250	—7	b 1.4712	d. 8	1.14	20.86	12.7	29.14
Leaves.....	Golden yellow; strong minty odor; bitter, cooling, slightly pungent taste.			b 1.4720		4.80	43.40		
Tops.....	Greenish yellow; agreeable, flowery odor; bitter, slightly pungent, cooling taste.			b 1.4738		3.30	28.29		

a At 24° C.

b At 22° C.

c Turbid in 1½ volumes or more.

d Turbid in 2 volumes or more.

During all the stages of growth the content of free acetic acid is consistently higher in the oils from the leaves and tops than in the oils from the whole herb. High acidity is usually accompanied by a correspondingly high percentage of menthyl acetate. This is clearly demonstrated by the oils from the leaves and tops at the flowering and fruiting stages in 1910, when the percentage of acid varied from 1.14 to 4.8 and the menthyl acetate from 20.86 to 43.4 per cent.

The ester content of the oils from both leaves and tops increases as the plant matures, the fruiting stage producing the oils richest in this constituent. The percentage of esters in the oils from the leaves and tops is higher in nearly every instance than in the oil from the whole fresh herb. It is very probable, therefore, that the esterification of the acetic acid and menthol takes place most readily in these parts of the plant. The formation of esters is no doubt less in the stems, which accounts for the lower ester content of the oil distilled from the whole plant.

The percentage of free menthol in the leaves and tops during the various stages does not seem to bear any constant relationship to the ester content or to the free menthol content of the oil from the whole plant. The total menthol of leaves and tops, however, is higher in nearly all cases than that of the fresh herb.

It would seem from the foregoing results that the formation of the principal constituents of peppermint oil, namely, menthyl acetate and menthol, takes place chiefly in the leaves and tops of the plants, beginning at an early stage of growth and increasing as the plant matures.

EFFECT OF LIGHT AND SHADE.

In a study of the effect of soil and climatic conditions upon the constituents of plants the factor of light is considered important by certain investigators.

Géneau¹ states that strong light has a favorable effect upon the decomposition of carbon dioxid and the elimination of water vapor in plants. Berthelot² has observed that plants grown in the shade contain noticeably greater proportions of water than plants grown in the light.

Charabot and Hébert³ have investigated the peppermint plant and find that darkness considerably reduces the percentage of volatile oil in the plant. It is also stated by these investigators⁴ that plants kept in the shade consume the terpene constituents of the oil.

For the purpose of ascertaining the effect of shade on the yield and composition of peppermint oil, cultural experiments were conducted through two successive years upon a small plat of peppermint grown under a slat shade, whereby the light intensity was reduced about 50 per cent, and upon a similar plat grown in the open to serve as a check. The plants were harvested during the flowering stage and distilled in the fresh condition.

The physical and chemical properties of the respective oils were determined and for comparison are presented in Table VI.

It will be observed that in 1910 the yield of oil was the same from both the shade-grown and the unshaded plants, while in 1911 the yield from the shade-grown plants was slightly in excess of that from the unshaded plants. These results are at variance with those of earlier investigators with respect to the formation of oil in shade-grown plants. The plants described were, however, grown in only partial shade, which may have been the optimum condition for the formation of the oil in 1911.

¹ Géneau de Lamarlière, Léon. Recherches physiologiques sur les feuilles développées à l'ombre et au soleil. *In* Rev. Gén. Bot., t. 4, p. 494. 1892.

² Berthelot. Sur la marche générale de la végétation; plante développée à l'ombre et au soleil. *In* Compt. Rend. Acad. Sci. [Paris], t. 123, no. 3, p. 139-144. 1899.

³ Charabot, Eugène, and Hébert, Alex. Formation des composés terpéniques dans les organes chlorophylliens. *In* Bul. Soc. Chim. Paris, s. 3, t. 31, p. 402-409. 1904.

⁴ Charabot, Eugène, and Hébert, Alex. Consommation des matières odorantes chez la plante étiolée. *In* Bul. Soc. Chim. Paris, s. 3, t. 33, p. 580-585. 1905.

TABLE VI.—*Comparison of the yields, the physical properties, and the chemical composition of peppermint oils distilled from shade-grown and from unshaded plants.*

Items of comparison.	1910		1911	
	Shade-grown plants.	Unshaded plants.	Shade-grown plants.	Unshaded plants.
Yields and physical properties:				
Yield, per cent.	0.13.....	0.13.....	0.15.....	0.9.
Color.....	Pale yellow.....	Pale yellow.....	Pale golden yellow.	Dark golden yellow.
Odor.....	Very mild, minty..	Mild, agreeable, minty.	Mild, agreeable, minty.	Strong minty, characteristic.
Taste.....	Fatty, cooling, slightly bitter, and pungent.	Fatty, strong, cooling, pungent.	Strongly bitter, pungent, minty.	Bitter, pungent, strong, cooling.
Specific gravity (at 23° C.).	0.9343.....	0.9273.....	0.9192.....	0.9233.
Rotation, in 50 mm. tube, degrees.	-2.24.....	-5.7.....	-3.4.....	-7.3.
Refraction.....	1.4724, at 22° C.....	1.4820 at 22° C.....	1.4708, at 23° C.....	1.4722, at 23° C.
Solubility in 80 per cent alcohol, volumes.	0.7; turbid in 1½ volumes or more.	0.6; turbid in 2 volumes or more.	0.7; very turbid in 2 volumes or more.	0.75; very turbid in 1½ volumes or more.
Chemical composition (per cent):				
Free acids (calculated as acetic acid).	0.....	0.03.....	0.07.....	0.20.
Menthyl acetate.	10.96.....	11.67.....	13.08.....	13.79.
Free menthol.....	24.43.....	30.94.....	31.20.....	34.11.
Total menthol.....	33.07.....	40.13.....	41.50.....	44.97.

Compared with the oils from unshaded plants, the oils obtained from the shade-grown plants in 1910 showed a slight increase in the specific gravity and in 1911 but very little difference. The rotation and refraction of the oils from the shade-grown plants were lower in both years than in the oils from the unshaded plants. In solubility but little difference was noticed. In general appearance, however, the oils from the shade-grown plants were somewhat lighter in color and showed a slight difference in odor and taste. The marked difference in rotation of the two oils during both seasons is especially significant and denotes differences in composition.

The free acidity of the oils from the shade-grown plants is seen to be lower in both seasons than that of the oil from the unshaded plants, as is also the content of menthyl acetate, free menthol, and total menthol. The results indicate that both esterification and the formation of menthol are retarded by the absence of light, possibly because photosynthetic activities are greater in the presence of light.

EFFECT OF FROST ACTION.

From the considerations presented in the foregoing paragraphs it seems probable that in the peppermint plant the formation of certain compounds and the breaking down of others is dependent upon a number of factors, some of which stimulate while others retard, or possibly inhibit, the reactions taking place in the plant tissues. The changes which take place in a volatile oil as a result of the action of

these factors upon the process of synthesis in the plant are usually confined to the least stable constituents.

The process of esterification is common to most aromatic plants and is more or less affected by the conditions of temperature, light, and moisture under which the plant grows. Among these factors the effect of frost action upon the formation of aromatic compounds in plants has perhaps received least attention, and whether it promotes or retards the development of the odorous compounds in the oil is not yet definitely known. Charabot,¹ in an investigation on the relation of esters to the chlorophyl in plants, states that the effect of reduced temperature on the formation of esters is opposite to that of either intense light or a dry atmosphere. Schimmel & Co.,² in a report on the oil distilled from frozen leaves of the bergamot mint (*Mentha citrata* Ehrh.) grown in Florida, state that the yield of oil did not differ materially from that of the unfrozen plant, but that the physical and chemical properties disclosed marked variations. The most striking difference was the large increase in ester content (linalyl acetate) of the oil from the frozen leaves, the oil from the unfrozen plants containing only one-third as much ester.

In the course of some studies on the peppermint plant made at Arlington Farm during the seasons of 1910 and 1911, advantage was taken of the second crop, which came on late in the autumn, to collect some data regarding the effect of frost action upon the new growth of plants. These plants were from 12 to 18 inches tall, in an early although fairly vigorous stage of growth, and bore an abundance of leaves. After having been exposed to several heavy frosts the plants were distilled and the oils subjected to a thorough examination. As a basis for comparison, plants unaffected by frost were distilled each year. In 1910, plants from the first crop in an early stage of growth, and consisting mainly of leaves with no buds, were distilled on July 25. In 1911, plants from the second crop, which had made a short growth after the harvesting of the first crop, were distilled on October 30. These plants consisted of leaves with a few buds. Table VII gives the results of the examinations.

An inspection of Table VII shows that the yield of oil from both the frozen and unfrozen plants is practically the same, although it is considerably lower than that from fully grown plants, the yield from which is approximately double that here recorded. The oil from the frozen plants had the more agreeable and flowery odor, which may be attributed to the very high content of esters of menthol. The cooling sensation resulting when the oil from the frozen plants was applied to the tongue was noticeably greater than from that of

¹ Charabot, Eugène. Sur le rôle de la fonction chlorophyllienne dans l'évolution des composés terpéniques. In Compt. Rend. Acad. Sci. (Paris), t. 132, no. 3, p. 159-161. 1901.

² Schimmel & Co. (Fritzsch Brothers). Semiannual Report, p. 14. Miltitz, London, New York, Nov., 1908.

the oil from the unfrozen plants, possibly because of the greater proportion of menthol in the first-mentioned oil.

The physical constants reveal marked differences in the rotation and some differences in the solubility in 80 per cent alcohol. The higher rotation of the oil from the frozen plants is attributable to the presence of a greater quantity of the strongly levogyrate compounds, menthol and menthyl acetate.

TABLE VII.—*Comparison of the yields, the physical properties, and the chemical composition of peppermint oils distilled from frozen and from unfrozen plants.*

Items of comparison.	1910		1911	
	Frozen plants.	Unfrozen plants.	Frozen plants.	Unfrozen plants.
Physical properties:				
Yield, per cent.....	0.065.....	0.07.....	0.11.....	0.077.....
Color.....	Pale straw.....	Pale yellowish green.....	Dark golden yellow.....	Pale golden yellow.....
Odor.....	Mild, flowery, characteristic minty.....	Strongly minty.....	Flowery, not strongly minty.....	Strongly minty.....
Taste.....	Bitter, pungent, and exceedingly cooling.....	Pungent, slightly bitter, cooling.....	Bitter, pungent, and cooling.....	Bitter, slightly pungent, cooling.....
Specific gravity.....	0.9107, at 24° C.....	0.9112, at 24° C.....	0.9155, at 23° C.....	0.9180, at 23° C.....
Rotation, in 50 mm. tube, degrees.....	-11.5.....	-8.45.....	-16.5.....	-11.7.....
Refraction.....	1.4592, at 25° C.....	1.4689, at 22° C.....	1.4580, at 23° C.....	1.4621, at 23° C.....
Solubility in 80 per cent alcohol, volume.....	0.4; clear in excess.....	0.6; turbid in 1½ volumes or more.....	0.8; faintly turbid in 3½ volumes or more.....	0.5; turbid in 2½ volumes or more.....
Chemical composition (per cent):				
Free acid (calculated as acetic acid).....	0.09.....	0.086.....	0.09.....	0.12.....
Menthyl acetate.....	24.3.....	8.8.....	40.66.....	31.82.....
Free menthol.....	40.7.....	31.8.....	28.93.....	9.99.....
Total menthol.....	67.8.....	38.7.....	69.97.....	35.61.....

The oils from the frozen plants, being readily soluble, remain more or less clear when an excess of 80 per cent alcohol is added, whereas the oils from the unfrozen plants become turbid in one and one-half volumes or more of alcohol. In the oils from the frozen plants, therefore, a higher content of the easily soluble menthol and menthyl acetate, and possibly a lower content of the more or less insoluble terpenes, may be expected.

In discussing the chemical constants of the oils it is noted that the quantity of free acids is nearly the same for all the oils. The ester content of the oils from the frozen plants, when calculated as menthyl acetate, was 34.3 in 1910 and 40.66 per cent in 1911, which is much higher than the ester content of the oils from the unfrozen plants. During both seasons the percentage of free menthol in the oils from the frozen plants exceeded that in the oils from the unfrozen plants. The total menthol content was also much higher in the oils from the frozen plants than in that from the unfrozen plants.

If, as in the ordinary esterification reactions, the formation of esters in the plant takes place by the action of the organic acids upon

the free alcohols with the elimination of water, it is possible that the end result of the reaction would be intensified provided there was some means whereby the water could be rendered incapable of reversing the reaction.

According to Charabot,¹ who has investigated ester formation in the peppermint plant, the esterification takes place in the green parts of the plant as a result of "chlorophyllic evaporation" of water from the leaves, while the process of oxidation of menthol to menthone takes place in the floral parts of the plant. It has been further demonstrated by Charabot and Hébert² that conditions which tend to increase the elimination of water favor the esterification in the plant. The addition of salt (NaCl) to the soil was shown to be followed by an increase in the percentage of esters in the oil. The probability that esterification in a plant is aided by the presence of an enzyme with a reversible action has also been suggested.³

Whatever the explanation of the wide variation in the oils may be, it seems evident that the effect of frost upon the peppermint plant tends to intensify esterification.

If esterification is favored by a reduced water content in the plant due to increased evaporation, as appears from the work of Charabot and Hébert, freezing may bring about the same result, either by checking the absorption of water by the plant or by removing from the sphere of action the water already contained in it. Also esterification may have continued after freezing by the aid of catalytic agents, the resultant water being frozen as formed, thus diminishing the chances of a reverse action.

Since the percentage of free menthol was slightly higher in the oil from the frozen plant, and as the menthol in the plant has been shown to be capable of oxidation to menthone, possibly another effect of freezing is to lessen oxidation in the plant tissues.

CONCLUSIONS.

Conditions of soil and climate are influential factors in the formation of oil and its constituents in the peppermint plant. Light sandy or loamy soils appear to be most favorable for the production of an oil of high quality.

The yield of oil distilled from fresh plants apparently decreases as the plant matures. Drying the plant before distillation results in a considerable loss of oil. The largest proportion of oil is found in the leaves and flowering tops.

¹ Charabot, Eugène. Recherches sur les migrations et les métamorphoses des composés terpéniques dans la menthe poivrée. *In* Bul. Soc. Chim. Paris, s. 3, t. 23, p. 466-474. 1900.

² Charabot, Eugène, and Hébert, Alex. Chemical investigations on the vegetation of perfume-yielding plants. *In* Bul. Sci. and Indus., Roure-Bertrand Fils, s. 1, no. 5, p. 24. 1902.

³ Charabot, Eugène, and Hébert, Alex. Recherches sur le mécanisme de l'éthérification chez les plantes. *In* Bul. Sci. et Indus. Roure-Bertrand Fils, s. 1, no. 4, p. 3-16. 1901.

The percentage of esters in the oils increases as the plants approach maturity. The menthol content of the oil bears a close relationship to the ester content. The free acidity and ester content of the oil distilled from dry plants is considerably higher than in the oil from fresh plants. The drying of the plants causes changes favorable to esterification, while the percentage of free and total menthol in oils distilled from dried plants is also uniformly high.

The formation of esters and menthol takes place most readily in the leaves and tops of the plant, the metabolic processes showing increased activity as the plant matures.

The effect of shade upon the peppermint plant is to decrease esterification and the formation of menthol, and is due possibly to the lessened activity of the elimination of water by the plant.

The action of frost noticeably increases esterification and the formation of menthol.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 455

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.

PROFESSIONAL PAPER

December 2, 1916

THE DRYING FOR MILLING PURPOSES OF DAMP AND GARLICKY WHEAT.

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Baltimore, Md.*

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INTRODUCTION.

In connection with investigations to determine the best method of artificially drying, cleaning, and handling garlicky wheat for milling purposes, data were obtained to show the proper temperature at which wheat should be dried for milling purposes. The results cover both the drying of garlicky wheat and the drying of damp wheat that is free from garlic. The milling and baking tests of the wheat used in the various experiments were made by L. M. Thomas, Assistant in Charge of the United States Grain-Standardization Laboratory at Agricultural College, N. Dak.

The artificial drying of wheat facilitates the removal of the garlic bulblets by subsequent cleaning. It is a process that can be used to best advantage by mills. Experiments pertaining to the removal of garlic from wheat after artificial drying were first described by

Dr. J. W. T. Duvel.¹ The first step consists in reducing the moisture content of the wheat to a relatively low percentage, after which approximately all of the garlic can be removed by thorough cleaning. Although even by this process it is impossible to remove absolutely all of the garlic bulblets, flour commercially free from the odor of garlic can be manufactured if it is carefully handled. This method is most practicable for flour mills, in that the large amount of moisture lost in drying can be largely replaced by properly tempering the wheat before milling.

THE DRYING OF DAMP WHEAT.

A car of damp wheat containing a moisture content of 16.3 per cent was dried down to 12.9 per cent in a commercial drier. This wheat was dried for one hour at a temperature of approximately 140° F. before being dropped into the cooling compartment of the drier. Representative samples of 5 bushels each were taken from this lot of wheat before and after drying for experimental milling and baking tests.

The results of the baking tests with the straight flours made from these samples and from mixtures of equal portions thereof are given in Table I.

TABLE I.—*Results of baking tests with flour made from natural and dried wheats and from a mixture of both.*

Description of samples.	Water absorption of flour.	Volume of loaf.	Score.		Remarks concerning crumb.
			Texture of loaf.	Color of crumb.	
	<i>Per cent.</i>	<i>C. c.</i>			
Wheat, natural ¹	56.8	2,101	92.0	97.3	A little gray.
Wheat, dried at 140° F. ¹	56.5	2,085	91.6	95.9	Do.
Wheat mixture, equal quantities of above..	56.2	2,070	91.6	95.3	Do.

¹ Average of two tests.

Table I shows the results of the baking tests of flour made from the wheat before and after drying. The differences are in every case found to be very slight and within the range of experimental error. When correlated with the tests that follow, these results indicate that 140° F. is the proper temperature at which to dry damp wheat.

THE DISTRIBUTION OF GARLIC.

Wild garlic is a native of western Europe and was probably introduced into the United States early in the eighteenth century. As

¹ Garlicy wheat. In U. S. Dept. Agr., Bur. Plant Indus. Bul. 100, p. 21-30, pl. 1-2. 1907.

early as 1754 garlic was quite common in wheat in parts of Pennsylvania.¹

The wild onion, or garlic (*Allium vineale*), is found in the Atlantic coast region from Massachusetts to Georgia and as far inland as Missouri (fig. 1), and in a large part of that territory it is the worst weed pest.²

THE AMOUNT OF MOISTURE IN GARLIC BEFORE AND AFTER DRYING.

Seven different lots of garlicky wheat, aggregating about 50,000 bushels, were followed through a commercial drier in order to note the effect of the different operations on the garlic in the wheat. Several samples of each lot of wheat were taken before going into and after coming out of the drier. The garlic was separated from each of these samples and the moisture content determined by drying to constant weight in a water-bath oven. The maximum amount of water in the garlic before drying was 41.74 per cent and the minimum 25.85 per cent, while the average was 37.92 per cent. The maximum amount of water found in the garlic after drying was 29.73 per cent and the minimum 18.15 per cent, with an average of 23.41 per cent. The average reduction in the moisture content of the garlic during the drying was 14.51 per cent. The average reduction in the moisture content of the wheat was 5.1 per cent, the average moisture of the wheat before drying being 13.9 per cent and after drying 8.8 per cent.

A great many of the garlic bulblets from the dried wheat were found to contain considerable moisture after a severe drying, while other bulblets from the same lot were shriveled and brittle. This was caused in part, no doubt, by the fact that the hot air was not equally distributed to every particle of wheat and garlic in the drier, and probably also by the fact that the garlic was in different stages of maturity, some of the bulblets when they went into the drier containing much less moisture than others.

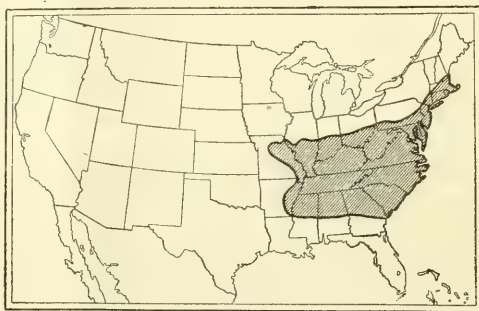


FIG. 1.—Sketch map of the United States, showing the distribution of the wild onion, or garlic.

¹ Pipal, F. J. Wild garlic and its eradication. Ind. Agr. Exp. Sta. Bul. 176, 43 p., 16 fig., 8 pl. 1914.

² See Cox, H. R., Wild onion: Methods of eradication, U. S. Dept. Agr., Farmers' Bul. 610, 8 p., 7 fig. 1914.

THE LOSS OF MOISTURE IN GARLIC IN WARM AND IN HOT WHEAT.

One lot of about 500 bushels of hot wheat was run into a bin directly from the heating chamber of the drier without cooling, in order to note the effect of hot wheat on the garlic. The temperature of the air in the drier during the drying of this lot of wheat was 180° F. Five samples of this hot wheat were placed in thermos bottles, and the temperature of the wheat was found to range from 140° to 154°, with an average of 148° F. The moisture content of this dried wheat ranged from 8.2 per cent to 8.8 per cent, with an average of 8.5 per cent. The moisture of the garlic taken from the drier was found to be 27.4 per cent. After the wheat had been in the bin for 48 hours the temperature decreased to 114° F. and the moisture content of the garlic was reduced from 27.4 per cent to 14.23 per cent, a difference of 13.17 per cent. At the end of 5 days and 22 hours samples were again taken, when the temperature of the wheat was found to be 104° F. and the moisture content of the garlic 11.04 per cent, a total reduction in the moisture content of the garlic of 16.36 per cent in the time specified.

Another lot of approximately 500 bushels was run from the drier after being partly cooled. The moisture content of this wheat from the drier was 9.1 per cent. The moisture content of the garlic taken from this wheat from the drier was 26.25 per cent. The moisture content of the garlic after being held for 70 hours in the bin was 20.34 per cent, a reduction of 5.91 per cent. The wheat at the end of 70 hours was still warm, the temperature being 106° F.

Wheat dried to a moisture content of 8 or 9 per cent will not deteriorate or start fermentation if left in a bin warm. This method assists in removing the moisture from the garlic, which in turn makes the garlic lighter and more easily removed from the wheat.

THE QUANTITY OF GARLIC BEFORE AND AFTER CLEANING.

The average quantity of garlic in this wheat before drying was 14 one-hundredths of 1 per cent, and the average quantity of garlic in the wheat from the drier was 13 one-hundredths of 1 per cent. The average quantity of garlic in the wheat going to the rolls after a very thorough cleaning was 3 one-hundredths of 1 per cent, which is equivalent to approximately eight or ten dried garlic bulblets in each pound of grain. This quantity of garlic in wheat, if taken in its natural state, when the bulblets are hard and firm, has been found to impart a slight garlicky odor to the flour. Fortunately, however, the drying process changes the strong pungent odor of garlic to a milder one, so that it requires a higher percentage of dried garlic to affect the odor of the flour.

TEMPERING THE DRIED WHEAT.

Considerable care should be taken in tempering wheat artificially dried to a low moisture content. Ordinarily one tempering will not be sufficient to bring the moisture content of the wheat back to the normal amount for good milling. For the best results the wheat should be held in the bin at least 24 hours, if not longer, after the last tempering, to allow the water to be more evenly distributed. If the wheat is handled after it is tempered and then held in the bin for several hours, the wet and the dry lots will be more thoroughly mixed and the moisture uniformly distributed, thus making a more even mixture at the rolls.

The average moisture content of seven different lots of wheat going to the drier was 13.9 per cent and the average moisture content after drying was 8.8 per cent. The average moisture content of the dried wheat at the rolls after one tempering was 11.4 per cent, or 2.5 per cent below that of the natural wheat before drying.

COMMERCIAL MILLING TEST.

In the commercial milling experiment three cars of wheat, or approximately 3,000 bushels, were very thoroughly mixed. This wheat had a small quantity of garlic in it, but under ordinary commercial practices it would be classified as garlic-free wheat; that is, wheat which after a thorough cleaning would make flour free from the odor of garlic.

The moisture of the wheat going into the drier in this experiment, as shown in Table II, was 13.6 per cent, and that to the bin from the drier 8.1 per cent. The moisture of the natural wheat at the rolls was 13.2 per cent and of the dried wheat at the rolls after one tempering 11.9 per cent, a difference of 1.3 per cent.

TABLE II.—*Moisture content of natural and dried wheats, the average number of garlic bulblets per pound of wheat milled, the average percentage at the rolls, and the odor of the flour.*

Description of sample.	Moisture of wheat as milled.	Garlic at the rolls.		Odor of the flour.
		Bulblets per pound.	Per cent.	
Natural wheat	<i>Per cent.</i> 13.2	8.6	0.035	Garlicky. Natural, except 3 per cent of lowest grade.
Dried wheat	11.9	5.0	.019	

The dried wheat made flour 97 per cent of which was free from the odor of garlic, while all of the flour made from the natural wheat had a garlicky odor. The odor of garlic when present always is

more pronounced in the low-grade flours. In the foregoing test the flour made from the dried wheat gave only 3 per cent classed as garlicky, which was the lowest grade, while the flour made from the natural wheat was 100 per cent garlicky. The rolls receiving garlicky wheat, whether dried or natural, will have to be washed frequently, for the garlic bulblets eventually gum the rolls to such an extent as to give the flour the odor of garlic.

DRYING AND MILLING TESTS OF GARLICKY WHEATS HAVING A HIGH, MEDIUM, AND LOW MOISTURE CONTENT.

Table III shows the results from three different lots of wheat having a low, medium, and high moisture content, respectively, which were dried at a temperature fluctuating from 190° to 200° F. The low-moisture or dry wheat contained 12.7 per cent and the medium-dry wheat 13.9 per cent of water, while the high-moisture wheat contained 16.6 per cent. Each lot was dried the same length of time (one hour) and at the same temperature as nearly as practicable. Two bushels of wheat were taken from each lot, both before and after drying, and a milling and baking test was made of each lot in order to note the effect of drying.

Table III also shows the results of baking tests with flour made from these three lots of wheat of low, medium, and high moisture content dried at a temperature of 190° to 200° F.

TABLE III.—*Moisture content of wheat before and after drying for one hour at temperatures ranging from 190° to 200° F., and the results of baking tests of flour made therefrom.*

Lot No.	Moisture content (per cent).		Baking results (average of two tests)—					
	Before drying.	After drying.	Sample of flour from wheat—	Water absorption.	Volume of loaf.	Score.		Remarks concerning crumb.
						Texture of loaf.	Color of crumb.	
1, low moisture.....	12.7	8.0	{Before drying... {After drying...	<i>Per cent.</i> 56.0 56.2	<i>C. c.</i> 1, 885 1, 879	91.2 93.0	94.2 96.0	Creamy. Do.
2, medium moisture.....	13.9	.....	{Before drying... {After drying...	55.3 55.4	1, 937 1, 856	91.7 90.0	97.7 97.7	Do. Do.
3, high moisture.....	16.6	9.3	{Before drying... {After drying...	56.0 55.9	2, 026 1, 928	95.0 93.5	96.0 96.0	Do. Do.

From these data it appears that more injury is done to the flour by drying wheat having a high moisture content at a temperature of 190° to 200° F. than in drying wheat with a low moisture content. The decrease in loaf volume of the wheat having a moisture content of 16.6 per cent was 98 c. c., or 4.83 per cent, and the decrease in the

loaf volume of the wheat having a moisture content of 13.9 per cent was 81 c. c., or 4.17 per cent. The decrease in the loaf volume of the wheat with a moisture content of 12.7 per cent was only 6 c. c., or 0.03 per cent. The texture of the loaf was injured in the wheats having a high or a medium moisture content, but it was slightly superior in the low-moisture wheat. In these tests an injury was done to the wheats having a medium or a high moisture content (fig. 2) in the



FIG. 2.—Loaves from natural wheat and from wheat artificially dried: A, Loaf from natural wheat, with a volume of 2,050 c. c. and a texture of 95; B, loaf from wheat dried at a temperature of 190° to 200° F., with a volume of 1,946 c. c. and a texture of 93.5. The moisture content of the natural wheat was 16.6 per cent.

process of drying at a temperature of 190° to 200° F., but none was noticed in the low-moisture wheat.

DRYING WHEAT AT DIFFERENT TEMPERATURES.

Table IV shows the results of tests before and after drying 6,000 bushels of wheat, the temperature of the hot air in the drier at the time these tests were made, the length of time the wheat was in the drier, and the moisture of the wheat going into the rolls. The wheat was divided into four different lots of approximately 1,500 bushels each. One lot of the natural wheat was milled as such, and the other three lots were milled after being dried at temperatures of 140°, 160°, and 180° F.

Baking tests were made from the flour milled from the wheat dried at these different temperatures and the results are also shown in Table IV.

TABLE IV.—*Moisture content of wheat dried at different temperatures and the results of baking tests of flour made therefrom.*

Description of sample of wheat.	Moisture content (per cent).			Length of time in drier.	Baking tests of flour.				
	Before drying.	After drying.	At rolls.		Water absorption.	Volume of loaf.	Score.		Remarks concerning crumb.
							Texture of loaf.	Color of crumb.	
				Hours.	Percent.	C. c.			
Natural.....	13.3	.....	13.4	.....	55.9	2,003	94.0	100	Slightly gray.
Dried at—									
140° F.....	13.5	8.9	12.8	1½	56.2	2,050	93.0	97	A little gray.
160° F.....	13.7	8.4	13.3	1½	55.9	2,040	93.5	97	Do.
180° F.....	13.4	7.3	10.5	1½	55.9	1,933	92.5	95	Gray.

There was not very much difference between the bread made from the natural wheat and that from wheat dried at 140° and 160° F. The bread made from the wheat dried at 180° F. was slightly inferior (fig. 3). The loaf made from the natural wheat had a smaller vol-



FIG. 3.—Loaves of bread from natural wheat, from wheat dried at 180° F., and from wheat dried at 140° F.: A, Bread from natural wheat, with a loaf volume of 2,003 c. c. and a texture of 100; B, bread from wheat dried at 180° F., with a loaf volume of 1,933 c. c. and a texture of 95; C, bread from wheat dried at 140° F., with a loaf volume of 2,050 c. c. and a texture of 97.

ume than either of the loaves from the wheat dried at 140° and 160° F., but had a slightly better texture and color. These differences can easily be attributed to the nature of the test and are within the range of experimental error. Moreover, it is extremely difficult to mix 6,000 bushels of wheat (four cars in this case) in such a manner that samples of the flour taken during the process of milling will give exactly duplicate results in a baking test. The differences obtained from these three lots might have been due to actual differences in the samples, which are likely to be found in tests of this kind.

THE DRYING OF WHEAT AT 140° F.

Three different lots of wheat were dried at a temperature of 140° F. and a 2-bushel sample was taken before and after drying, a milling and baking test being made of each. The wheat was subjected to the heat in the drier for 1 hour and 40 minutes. The results of the drying and of the baking tests of these three lots of wheat before and after drying at approximately 140° F. are shown in Table V.

TABLE V.—*Moisture content of wheat before and after drying for 1½ hours at a temperature of approximately 140° F., and the results of baking tests of flour made therefrom.*

Lot No.	Moisture content.		Temperature of hot air (° F.).			Baking tests.					
	Be-fore dry-ing.	After dry-ing.	Maxi-mum.	Mini-mum.	Aver-age.	Sample of flour from wheat—	Water ab-sorp-tion.	Vol-ume of loaf.	Score.		Remarks concern-ing crumb.
									Tex-ture of loaf.	Color of crumb.	
1.....	<i>P. ct.</i> 13.3	<i>P. ct.</i> 9.0	156	130	143	{Before drying. {After drying..	<i>P. ct.</i> 59.7 58.8	<i>C. c.</i> 2,097 2,130	89.0 91.3	94.0 95.0	Creamy gray. Creamy.
2.....	13.7	9.8	154	132	141	{Before drying. {After drying..	58.8 59.1	2,027 2,143	90.0 90.0	92.3 95.0	Creamy gray. Creamy.
3.....	13.7	9.2	150	128	141	{Before drying. {After drying..	59.1 59.4	2,130 2,123	90.0 92.0	95.0 95.0	Do. Creamy gray.

In the first two lots there was six-tenths of 1 per cent more cockle in the samples as milled before drying than in the sample after drying, and it is possible that the presence of this cockle may have been the cause of the slightly better results from the milling and baking tests after drying than before drying.¹ In the last sample the amount of cockle was about the same before and after drying, and the results with regard to texture and loaf volume are approximately the same.

A number of samples of this wheat were taken as it left the heater division of the drier, placed in thermos bottles, and the temperature recorded. The lowest temperature obtained was 110° and the highest 132° F. The average temperature was 125° F.

SUMMARY.

The results of these investigations show practically no bad effects from the drying of wheat at 140° F. and indicate that this temperature is probably the most satisfactory for the drying of wheat, either with or without garlic, for milling purposes. More

¹ See Miller, R. C., Milling and baking tests of wheat containing admixtures of rye, corn cockle, kinghead, and vetch, U. S. Dept. Agr. Bul. 328, 24 p., 10 fig. 1915.

extensive experiments may show that wheat can be dried at a higher temperature than 140° F. without having a bad effect on the flour. Every test except one where the wheat was dried at 180° F. and above gave poorer results in the baking test from the standpoint of loaf volume and texture than when dried at 140° F.

If wheat is dried down to 9 per cent of moisture or below for the removal of garlic, great care must be taken in tempering it back to the normal amount of moisture. In order to restore the moisture content of the dried wheat to normal, which is important for good milling, the wheat should be tempered at least twice, and more if necessary. After the wheat is tempered it should be stored several hours before mixing or before another tempering is made, in order to allow the moisture to penetrate into the kernel. Several hours after the last tempering the wheat should be run from the bin and a thorough mixture made. This last process assists in mixing the dry and wet spots and makes a more even mixture at the rolls.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 456

Contribution from Office of Markets and Rural Organization
CHARLES J. BRAND, Chief



Washington, D. C.

February 5, 1917

MARKETING CREAMERY BUTTER.

By ROY C. POTTS, *Specialist in Marketing Dairy Products*, and H. F. MEYER,
Assistant in Marketing Dairy Products.

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INTRODUCTION.

The purpose of this bulletin is to present in logical sequence general facts and information regarding the packing, shipping, and marketing of creamery butter, which may be of interest to producers, distributors, and consumers of dairy products, as well as students and dairy officials. It is not intended that this bulletin should contain only new facts, but rather to make available in one publication a great deal of information regarding the marketing of creamery butter, which is of general interest. It should not be implied from the statement of any existing method or condition that the department thereby approves of such method or condition. A discussion of the more complex economic phases of butter marketing has been omitted purposely with the intention of treating them in future publications after further investigation and study.

A general survey and investigation was conducted in over 50 cities, in which the market requirements as well as methods and facilities for distribution were carefully studied. In each market visited numerous samples of butter were inspected and interviews were obtained with wholesale butter receivers, jobbers, brokers, man-

NOTE.—This bulletin should be of special interest to manufacturers and distributors of creamery butter in the United States and of general interest to dairy farmers who sell cream to creameries.

agers of chain stores, retailers, restaurant and hotel proprietors, officials of produce exchanges and butter boards, the official butter inspectors of the exchanges, managers of cold-storage warehouses, and officials of transportation companies.

UNIFORM QUALITY OF BUTTER AN IMPORTANT MARKET REQUIREMENT.

A frequent complaint made by the dealers and distributors in the markets is a lack of uniformity of the butter produced by many creameries, and an increasing quantity at certain seasons of inferior butter which is known as "undergrades." An inspection of this butter indicated that the inferior quality was often due to the use of cream of poor quality and to some extent to faulty manufacturing methods.

The requirements of various markets differ widely in some particulars, and butter of certain characteristics which is acceptable on some markets may meet serious objection on others. An illustration of this variation is found in New York and Philadelphia where certain consuming classes require butter of light color and salt, a firm waxy body, and a quick, fresh, sweet, clean flavor, while in Baltimore, Washington, and the markets of the South, the consumers generally prefer a deep yellow color, medium to heavy salt, and a reasonably fresh, clean flavor. Some markets require a high-flavored, firm-bodied, well-made piece of butter. Creamery men would do well to pay more attention to the importance of producing butter of the quality demanded by critical markets if they wish to obtain the highest market prices for their products. They should also know the requirements of the various markets and the channels of trade through which each grade of butter reaches that trade which demands it.

In the larger markets there are buyers for every grade of butter. The large retail chain store and chain restaurant systems in many cities often are confronted with the problem of obtaining large supplies of butter of uniform quality for their trade. They usually have been unable to buy directly from local country creameries or to obtain their supplies from the smaller jobbers and have been obliged, therefore, to buy from the larger wholesale receivers or centralizing creameries which may have large quantities of butter of a uniform quality. The retail chain store system is becoming an important factor in retail butter distribution. In some of the larger cities 40 per cent or more of the butter is retailed by chain stores. In many of the larger cities very satisfactory sales might be made to these stores by country creameries, if they produced butter of uniform quality and concentrated their product either at points within the areas of production or on the market where the chain store buyers could obtain such grades and quantities as they require. The employ-

ment of an inspector-instructor by various groups of country creameries in order to standardize the quality of their product would seem to be a move in the right direction and could be followed by standardization in methods of marketing and by the inspection of the butter and by branding it according to official grades. Greater uniformity in quality of butter is of primary importance to successful marketing, and creamery butter makers should give this phase of the subject most careful consideration.

COMMON FAULTS IN BUTTER.

The more common faults observed in the markets in the quality of butter are: Soft, leaky, open body; too much or not enough salt; too high or too light color; metallic flavors; high acid, unclean, and old cream flavors; streaks and mottles; mold on butter, also moldy and dirty packages. Butter possessing such faults, although not always classed as "undergrades," is often discriminated against by the critical buyer. During those seasons when the market receipts are heavy and the market is weak such butter can be moved only at low prices, and often sells at 6 to 8 cents below the better grades.

PACKAGES FOR BULK BUTTER.

The two styles of packages used for bulk butter are the "tub" and the "cube." In the Middle West the creameries use the 63-pound ash tub very generally, while in the New England States a preference is shown for butter put up in spruce tubs, of 10, 20, 30, 50, and 60 pounds capacity. When the local production in New England is insufficient to supply the demand, spruce tubs often are shipped to creameries in Michigan, Wisconsin, Iowa, Minnesota, Nebraska, and other western dairy States, as a premium of approximately half a cent per pound is usually paid by the New England buyers for butter packed in these tubs.

The use of the "cube" is confined almost wholly to the creameries located in the Pacific Coast States. (See fig. 1.) This container for bulk butter is made of fir and spruce. The shooks used for making the cubes are usually surfaced only on one side, which is placed toward the butter. The outside of the cube is therefore very rough and does not present an attractive appearance. Foreign markets to which considerable butter has been shipped from the Pacific coast have commented upon the rough surface of the cube and upon the lack of uniformity in size and net weight of the packages. The cube is a crude package in contrast to the containers used in New Zealand, which are neat, attractive, rectangular boxes, holding exactly 56 pounds, and are branded with the name of the creamery, export brand, and net weight on each end.

There has been considerable variation in the size of the cubes used, some holding 63 pounds, some 68, and others approximately 80 pounds. As a step toward standardizing the size of the cube, the San Francisco Wholesale Dairy Produce Exchange recently ruled that butter offered on the exchange as "extras" should be packed in cubes with sides, tops, and bottoms one-half inch in thickness

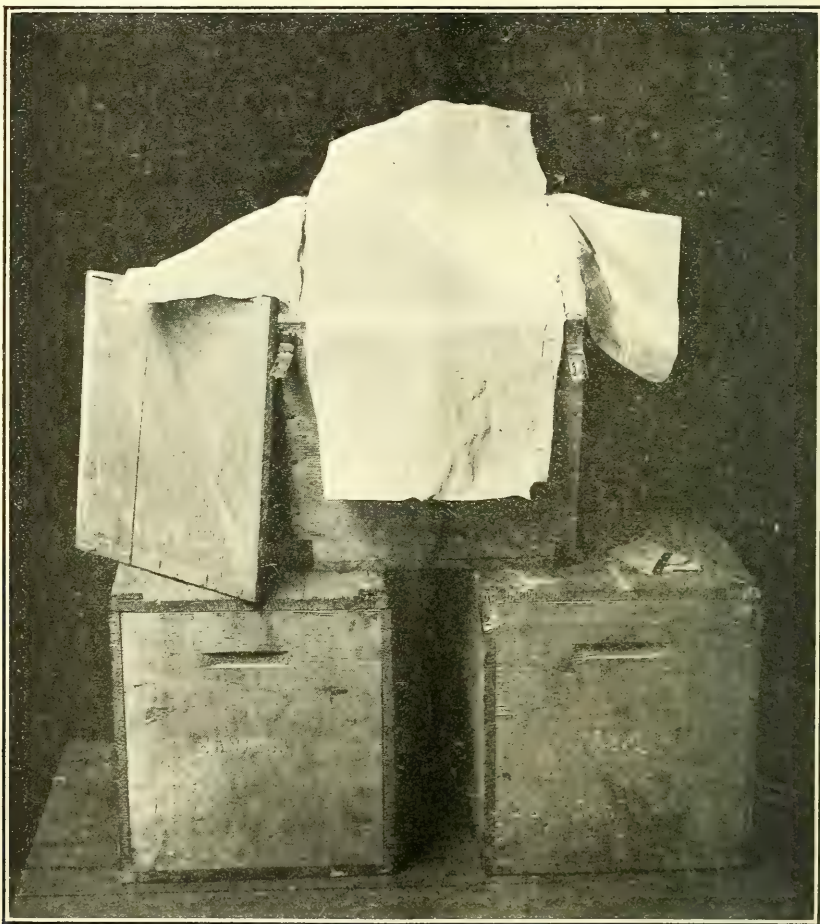


FIG. 1.—The cube is used on the Pacific coast for solid packed bulk butter. Its inside dimensions are $12\frac{1}{4}$ inches by $12\frac{1}{4}$ inches by $13\frac{1}{2}$ inches. Its net weight is approximately 68 pounds.

and ends seven-eighths of an inch in thickness, lumber to be surfaced on both sides, corners to be rounded, inside measurement $12\frac{1}{4}$ by $12\frac{1}{4}$ by $13\frac{1}{2}$ inches, and net weight to be marked on each end. The net weight of such a cube would be approximately 68 pounds. Cubes of a uniform size, which are neat and attractive in appearance, would be much more satisfactory and highly desirable both for local and foreign markets.

PREPARING PACKAGES FOR BULK BUTTER.

Before packing butter into tubs or cubes they should be scrubbed thoroughly with a stiff bristle brush and strong hot alkali water until the wood is bright and clean. (See fig. 2.) Then it is well to soak them in a tank of strong brine, as it tends to hold in check the development of mold. The soaking of the tub or cube also increases its moisture content and tends to reduce the shrinkage of the butter. The package should be paraffined before the parchment paper liner is applied, especially if the butter is to be placed in cold storage for a number of months. The liners should be soaked in a strong



FIG. 2.—White ash butter tubs which hold approximately 63 pounds of butter. The tub on the left presents an unattractive appearance, due to its moldy condition. Butter in clean tubs is sold more readily and at higher prices in the market.

solution of brine and carefully placed in the tub or cube so that the butter is protected from direct contact with wood and presents a neat and attractive appearance when the package is opened for inspection.

PACKING BULK BUTTER.

In packing butter in tubs or cubes the parchment liners should be retained in the proper place and the butter packed solidly so that it is free from holes. (See fig. 3.) In some of the larger eastern markets a great deal of butter is retailed direct from the tub, and to some extent this is done with cubes on the Pacific coast markets. When tub butter is retailed in this way, the tub and liner are removed, and it is cut with a wire into three horizontal layers. De-

pressions and holes in the butter caused by wrinkled liners and careless packing seriously injure the appearance of the butter, which should be neat and attractive to please the consumer.

BRANDING TUBS AND CUBES.

Butter shipped interstate in package form is required by Federal law to be branded with its net weight. Some States and cities require

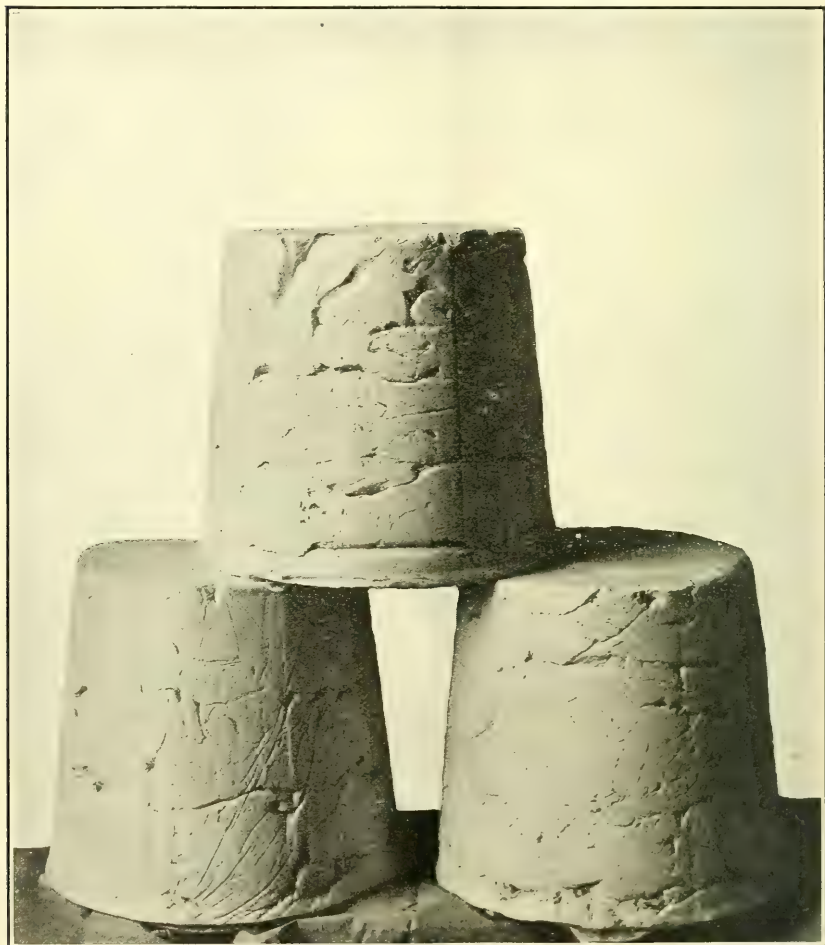


FIG. 3.—Tub butter which was poorly packed. The holes or pockets expose more surface, thus permitting greater shrinkage and development of mold.

the net weight to be branded upon consumers' packages. The branding of the tub and cube with the gross weight, net weight, and tare greatly facilitates the handling of bulk butter on the market. In the market inspection of a shipment of butter consisting of different churnings it would be convenient to have the number of the churning placed on each tub. The name or stencil number of the creamery and

the receiver's name and address should be stamped on the top of the tub or cube. The suggestions obtained from the practice in some foreign countries of having the name, address, and license number of the factory printed on each end of the cube or container, and of burning into the wood the net weight, are worthy of consideration.

MARKET METHODS OF WEIGHING TUB BUTTER.

Various methods of determining the net weight of butter in tubs are employed. (See fig. 4.) Some receivers accept the weights marked on the tubs by the creamery; others weigh each tub separately and mark upon the outside of the tub the gross weight in



FIG. 4.—Each shipment of butter is weighed and inspected by the wholesale receiver upon its receipt in his cooler or butter cellar.

full pounds. A number of the tubs are then stripped and the average net weight of actual butter in full pounds is obtained. The difference is taken as representing the tare of the tub. The rules of the Chicago Butter and Egg Board provide that a sufficient number of tubs in each lot (not less than 10 per cent) shall be weighed.

On the New York market (fig. 4), in determining the tare for the tub, the dealers usually make "test weights" as follows:

Weigh 3 tubs out of 12 or under.

Weigh 5 tubs out of 12 to 40.

Weigh 10 tubs out of 40 to 100.

Weigh 15 tubs out of 100 to 150.

Weigh 20 to 25 tubs out of a carload.

It is customary among the trade in weighing butter to require "up-weights," that is, the beam of the scale must balance against the upper rest, and when it does not the next lower pound is taken, fractional weights usually not being counted.

Since the net weight amendment to the pure food law became effective, distributors state that it is often unnecessary to weigh the butter, as the creamery's weights are accepted. It is very important, therefore, that creameries should weigh their butter correctly in order to obtain full weights. An allowance of one-half to three-fourths pound usually is made by creameries for shrinkage. Since the



FIG. 5.—In some markets a great deal of butter is retailed from tubs.

value of butter is higher than it was years ago when the present market methods of weighing were first adopted, it is even more important now that accurate methods of weighing be employed.

CONSUMERS' PACKAGES.

The trend at present in the market distribution of creamery butter is toward individual consumers' packages. The standard package most commonly used on eastern markets is the 1-pound print which measures $2\frac{1}{2}$ by $2\frac{1}{2}$ by $4\frac{3}{8}$ inches. In New York City, Boston, Buffalo, Cleveland, Charleston, and New Orleans the practice of retailing butter from tubs is still quite prevalent. (See fig. 5.) A large portion of the butter retailed is printed, wrapped, and placed in cartons

from tub butter. (See fig. 6.) Since the tub-shaped package is not the most desirable in some respects for cutting prints, a great deal of the butter distributed by the larger creameries is cut into prints at the creamery. Some creameries use the cube in preference to the tub for storage purposes, as it is better adapted to the cutting of prints.

The standard cube ($12\frac{1}{4}$ by $12\frac{1}{4}$ by $13\frac{1}{2}$ inches) used on the Pacific coast weighs about 68 pounds net and cuts out 64 full pounds of prints, thus leaving about 4 pounds of scrap to be repacked. A number of creameries in Ohio and Indiana are using cubes for their

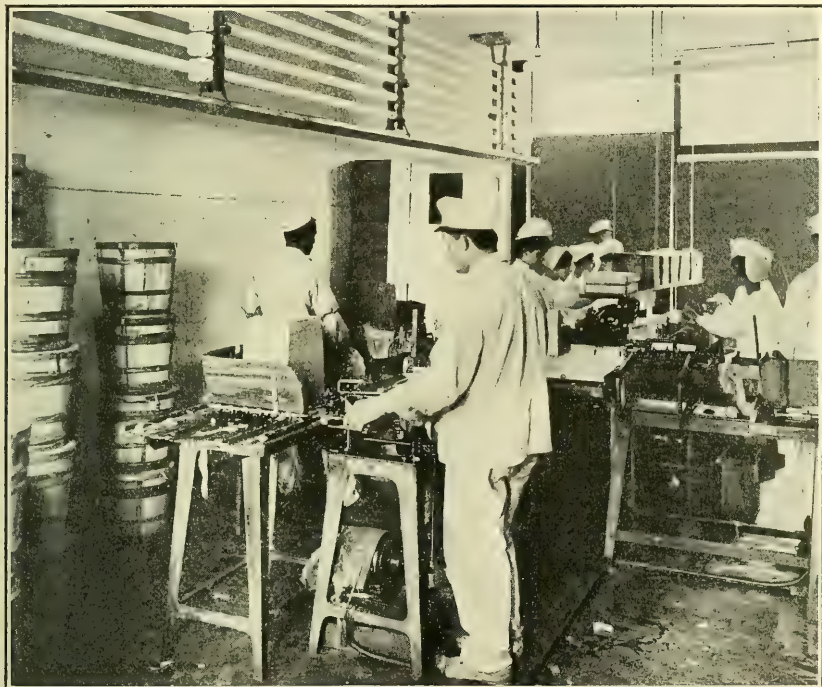


FIG. 6.—Wholesale distributors of butter in the larger markets use machines which cut and wrap the prints. The cartons are usually put on by hand.

shipments to Cincinnati, Louisville, Columbus, and other markets, as the dealers find them to be more economical in cutting prints from the standpoint of investment in printing equipment, labor, and shrinkage.

SHRINKAGE IN PRINTING TUB BUTTER.

The shrinkage in cutting prints from tub butter due to the loss of free moisture and a slight overweight allowed on each print is a larger item than ordinarily is considered. It has been found to vary from one-half to $1\frac{1}{2}$ pounds per tub. The various factors which

influence the loss of moisture are the temperature or firmness of the butter when printed; the firm, loose, or leaky body of the butter; the condition in which the moisture is incorporated; and the equipment and method employed in cutting the prints. In order to avoid large shrinkages or losses in printing, some receivers sort out those tubs which have a firm body and in which the moisture is well incorporated. With a loss of $1\frac{1}{2}$ pounds per tub in printing loose, leaky-bodied butter, it is evident that receivers cannot afford to pay as much for such butter as for butter in which the loss in printing is less.

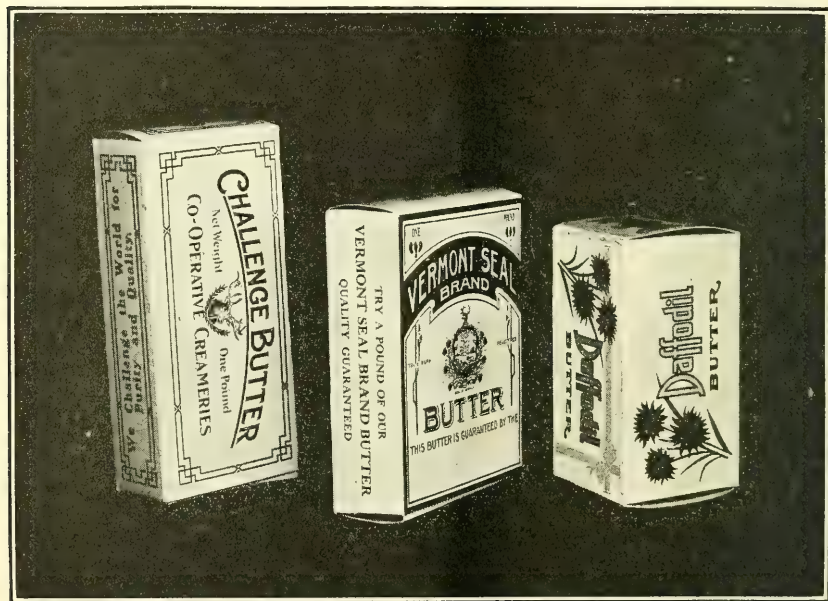


FIG. 7.—Three styles of 1-pound butter cartons are used. The right one is used by creameries in the Middle West, the center one is used in Vermont, and the one on the left on the Pacific coast.

THE USE OF CARTONS AND RETAILERS' BRANDS.

The use of cartons for print butter is increasing upon every market. Their advantages are that they make a more sanitary package which is more convenient for the retailer to handle, the quality of the butter is preserved longer, and, if branded with the name of the manufacturer or distributor, they furnish an advertising feature. (See fig. 7.) The larger chain stores handle print butter under their exclusive brands which are put up for them either at the creamery, by the jobber from whom they buy, or in their own butter printing department. Many retailers and wholesale distributors find it convenient and economical to furnish parchment wrappers and cartons bearing their private brands to creameries which for a small extra charge put their butter up for them.

LESS-THAN-POUND PACKAGES.

Two methods are used in marketing the less-than-pound packages. Some creameries use cartons which carry less than a pound. Others use a special frame on their printer and either halve or quarter the regular pound print ($2\frac{1}{2}$ by $2\frac{1}{2}$ by $4\frac{5}{8}$ inches). Figure 8 shows this method of marketing one-fourth, one-half, and 1-pound prints, by using the 1-pound carton. The individual pieces of butter are wrapped separately with parchment paper, consolidated into a pound package, and the whole wrapped with wax paper. When this method of putting up butter is employed an extra wholesale price of one-half to 1 cent a pound usually is obtained.

In some cities a large portion of the butter is sold in these styles of packages. This custom is prevalent in the South and is increasing

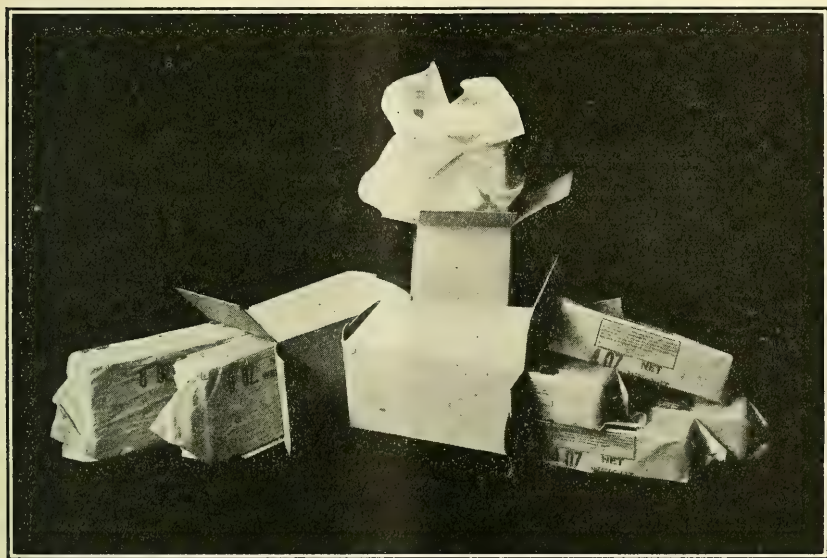


FIG. 8.—The standard carton used in the Middle West is $2\frac{1}{2}$ by $2\frac{1}{2}$ by $4\frac{5}{8}$ inches. It may be used for full-pound prints, four quarter-pounds, or two half-pounds.

in the North, particularly among consumers who demand small amounts, or prefer their butter in this style on account of its greater convenience in serving.

ORNAMENTAL PRINTS.

The custom is still quite prevalent in some of the eastern markets to imprint on each roll, crock, or print of butter an ornamental design or emblem. Illustrations of some of these designs are shown in figure 9. This is accomplished by an attachment to the cutter, which produces the desired impression as the butter passes beneath it. At the smaller creameries hand molds are used. The general use

of these ornamental designs is decreasing and undoubtedly will become obsolete as individual consumers' prints in standard cartons come into more general use.

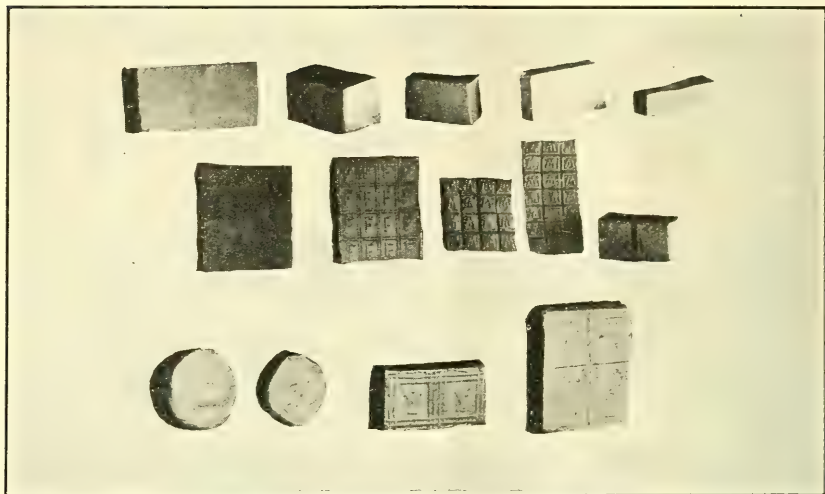


FIG. 9.—Ornamental prints are prevalent in New England. They are expensive to make and very inconvenient to pack and ship.

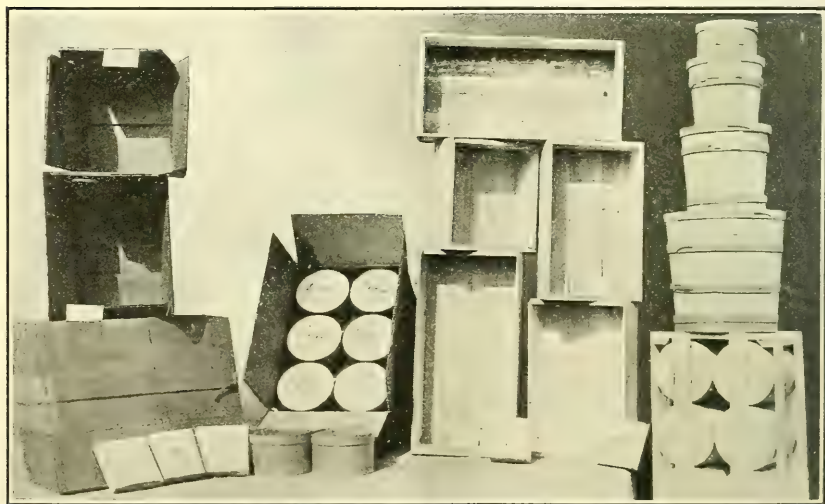


FIG. 10.—The unstandardized packages of New England require the use of various styles by a creamery. A standard package would be more convenient and satisfactory.

OTHER STYLES OF CONSUMERS' PACKAGES.

Throughout the New England States various styles of consumers' packages are in use. (See fig. 10.) The more common are known as the flat pound, flat half-pound, half-pound individual, 1-pound hotel bar, half-pound bar, western 1-pound prints, 2-pound brick,

5-pound rectangular box, 5-pound round box (wooden or fiber), and 10-pound tub. (See fig. 11.) This lack of uniformity means additional labor and expense for creameries when preparing butter for market. An effort is being made by the Vermont creameries to standardize the consumers' packages used in that State.

The customary consumers' packages on the Pacific coast are the 1 and 2-pound flat prints. The United States Navy in its contract for butter requires that a part of its supply be put up by the creameries in 5-pound sealed tins. (Fig. 12.) Butter for export to the Tropics usually is packed in similar tins, with the weights based on the metric system, and ranging from approximately one-half to 25-pound packages.



FIG. 11.—Tub butter is often repacked into smaller containers. The 5-pound wooden box is used as a consumer's package to some extent. The process is expensive as compared with cartoned prints.

SHIPPING CONTAINERS FOR BUTTER.

Fiber board, corrugated board, and wooden boxes are used as shipping containers for print butter. For city distribution, the fiber board boxes are used quite generally. When rehandling in transit is necessary or greater protection during the summer season is required, the wooden boxes often are preferred.

TRANSPORTATION FACILITIES FOR BUTTER.

In some sections the great bulk of the butter is shipped to the market by refrigerator freight. Throughout the dairy sections of the Middle West a regular scheduled refrigerator dairy freight service is

operated by the railroads or fast freight refrigerator companies, to move the shipments of butter from the creameries to eastern markets. The butter is collected from the creameries along the line in iced cars by "pick-up" service, and at junction or division points entire carloads are made up. The larger creameries which produce a carload or more of butter a week usually ship in carload lots directly from their plants. In distributing butter out of terminal markets such as Chicago, the various railroads extending into the South and East operate regular scheduled refrigerated package cars to certain cities where bulk cars are broken for distribution. In the more sparsely developed dairy sections and particularly with the smaller creameries,

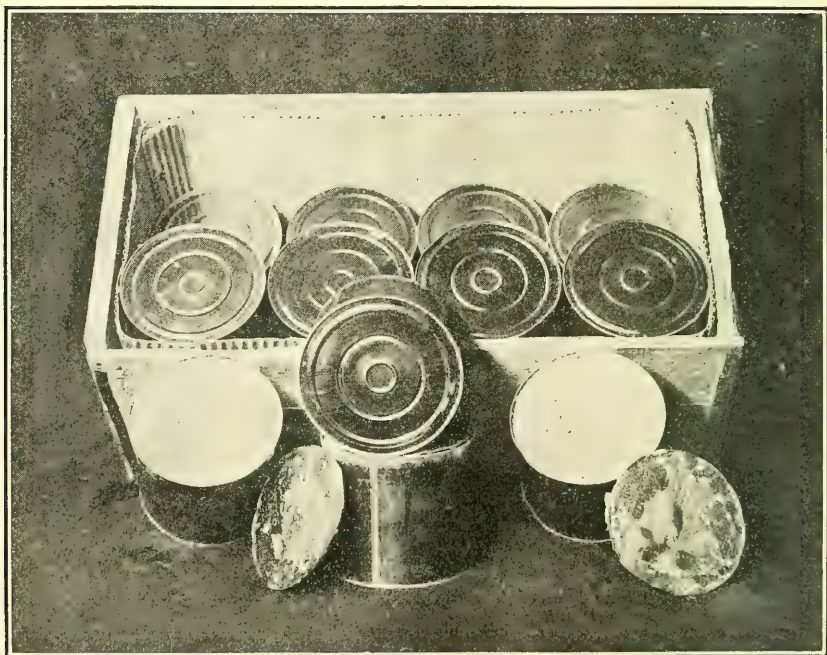


FIG. 12.—The butter exported to tropical countries is usually sealed in tins. The outside container is lined with corrugated fiber board and bound with strips of tin.

which market in local and neighboring cities, express service is commonly used.

Often express service may be used to advantage in reaching a junction point on a railroad through which a regular scheduled refrigerator car operates and from which refrigerator service by freight may be obtained to the market which the shipper desires to reach.

Arrangements prior to shipping should be made with the refrigerator car company to advance the local express charges, which they will later collect with the freight charges at destination.

The shipping tag on each package should carry the necessary routing instructions so that those handling the shipment may be fully informed of the service desired.

The advantages of this arrangement are twofold: First, movement of the product under refrigeration over a greater part of the route is obtained; second, the transportation costs are often less for the combined express and freight services than the regular through express charges.

REFRIGERATION SERVICE FOR BUTTER ON THE GREAT LAKES.

Inland waterway service has not been generally used for butter transportation. During the past two years, with three boats on the Great Lakes equipped with refrigerator compartments, a considerable quantity of butter was shipped by boat from Duluth, Minn., to Buffalo, N. Y., where much of it was reshipped by rail to eastern markets. This service has been generally satisfactory to those who have used it, and a saving in freight costs of approximately one-quarter cent per pound has been obtained.

OCEAN AND COASTWISE TRANSPORTATION.

Facilities for ocean and coastwise transportation of butter under refrigeration have been established to some extent. A large portion of the butter in coastwise trade is carried without refrigeration. This is true on both the Pacific and Atlantic coasts where the time between points is 48 hours or less. Some of the steamers have small refrigerator rooms which are used for butter as well as for milk, cheese, and other perishable products. With the development of trade through the Panama Canal, steamers sailing from the ports of the Pacific coast probably will be equipped with refrigeration so as to handle butter, as there is an increasing surplus on the Pacific coast for which markets may be obtained in the eastern and southeastern parts of the United States or in export trade.

COOPERATIVE CAR-LOT SHIPPING.

In various sections of the United States country creameries have cooperated in obtaining a special scheduled "pick-up" refrigerator-car service, and in concentrating local shipments into carload lots. By this means freight charges have been less and the butter has reached the market in better condition. When a number of creameries are located on the same railroad or in close proximity to each other, cooperative car-lot marketing may be a great advantage.

WHOLESALE TRADE ORGANIZATIONS.

The wholesale receivers of butter, eggs, and cheese in the larger markets have formed trade organizations. Through such organizations good fellowship is promoted and a meeting place or exchange room is maintained. At the meetings, which are usually held daily and are known as the "call" or "change," sales are conducted. These sales are in the form of an auction and each member has the privilege of posting his offerings and bids or listing them with the official in charge. In order to facilitate trading between the members

[illegible]

FIG. 13.—The wholesale trade organizations in the larger markets maintain bulletin boards on which market information is posted for the information of the trade.

rules and regulations have been adopted which provide (1) for the establishment of classes and grades of butter, (2) for an inspection service to apply these grades, and (3) for the adjustment of disputes in trading between members. Through the officers of the organization information is obtained for the members regarding the movement, prices, demand, and supply of butter in other markets and receipts at the local market. (See fig. 13.) They also obtain the benefits of cooperative action in matters which are of mutual interest.

such as State and city legislation, transportation and terminal facilities, and improvement of produce markets and marketing facilities.

MARKET GRADES OF CREAMERY BUTTER.

Market grades of creamery butter are necessary in order to facilitate trading and to establish market quotations for the various qualities. The purpose of grades is to establish a measure or standard for the qualities. A score card which recognizes the relative importance of the following characteristics is employed for the purpose of grading butter: Flavor (45), body (25), color (15), salt (10), and package (5). This gives a total of 100 points and the score the butter receives usually determines its grade.

The market grades of butter established by various wholesale produce organizations conform quite closely to a uniform standard. The interpretation or application of the grades by the butter inspectors may vary on the different markets and in educational and commercial scorings. These differences are due to a different requirement of quality which the inspector may use or a market may demand. Therefore butter scored 93 points by one inspector may be scored only 90 or 91 points by another, and an inspection certificate for an "extra" issued in one market may not be accepted as an "extra" in another. The requirements of each grade of creamery butter as established for the New York, Chicago, and San Francisco markets established for the New York, Chicago, and San Francisco markets by the wholesale trade organizations at each market are given herewith.

GRADES OF BUTTER ESTABLISHED BY THE NEW YORK MERCANTILE EXCHANGE FOR THE NEW YORK MARKET.

Extras.—Shall be a standard grade of average fancy quality in the season when offered under the various classifications. Ninety per cent shall conform to the following standard; the balance shall not grade below firsts:

Flavor.—Must be sweet, fresh, and clean for the season when offered.

Body.—Must be firm and uniform.

Color.—Not higher than natural grass, nor lighter than light straw, but should not be streaked or mottled.

Salt.—Medium salted.

Package.—Sound, good, uniform, and clean.

Firsts.—Shall be a grade next below extras and must be good butter for the season when made and offered, under the various classifications. Ninety per cent shall conform to the following standard; the balance shall not grade below seconds:

Flavor.—Must be reasonably sweet, reasonably clean, and fresh.

Body.—Must be firm and fairly uniform.

Color.—Reasonably uniform, neither very high nor very light.

Salt.—May be reasonably high, light, or medium.

Package.—Sound, good, uniform, and clean.

Seconds.—Shall be a grade next below firsts.

Flavor.—Must be reasonably good.

Body.—Must be solid boring.

Color.—Fairly uniform, but may be mottled.

Salt.—May be high, medium, or light.

Package.—Good and uniform.

Thirds.—Shall be a grade below seconds and may consist of promiscuous lots.

Flavor.—May be off-flavored and strong on tops and sides.

Body.—Not required to draw a full trier.

Color.—May be irregular or mottled.

Salt.—High, light, or irregular.

Package.—Any kind of package mentioned at time of sale.

Extra creamery may score either 91, 92, or 93 points at the discretion of the butter committee, who shall determine the required score from time to time in such manner that it shall represent an average fancy quality in the season when offered. But butter scoring more than required for extras shall be deliverable on a contract for extras, and may be branded as such at the request of seller or buyer. Any change in the standard score required for extras shall, after authorization by the butter committee, be announced by the caller at the opening of the next regular call and posted upon the bulletin board of the exchange and be effective 24 hours later.

The minimum score of Firsts shall at all times be 4 points below the score required for Extras.

The minimum score of Seconds shall be 5 points below the minimum score required for Firsts.

The minimum score of Thirds shall be 7 points below the minimum score required for Seconds.

GRADES OF BUTTER ESTABLISHED BY THE NEW YORK BUTTER AND EGG EXCHANGE (INC.) FOR THE NEW YORK MARKET.

This Exchange was organized in the spring of 1916 and adopted the same grades for Extras, Firsts, Seconds, and Thirds as the New York Mercantile Exchange. In addition a grade known as Specials was adopted with the following requirements:

Specials shall be the highest standard grade of fancy quality in the season when offered of creamery butter. Ninety-five per cent shall conform to the following standard and the balance shall not grade below an Extra.

Flavor.—Must be the sweetest, freshest, and cleanest for the season when offered and must have a pronounced aroma and quick flavor.

Body.—Must be firm and uniform.

Color.—Not higher than natural grass nor lighter than light straw and can not be wavy, streaked, or mottled.

Salt.—Medium salted.

Package.—Must be clean, uniform, and in good condition and the butter must be solidly packed.

GRADES OF CREAMERY BUTTER ESTABLISHED BY THE CHICAGO BUTTER AND EGG BOARD FOR THE CHICAGO MARKET.

Extras.—Shall consist of a grade of butter scoring 93 points or higher.

Flavor.—Must be fine, sweet, fresh, and clean, and good, sweet, and clean if held.

Body.—Must be firm and solid, with good grain or texture, free from salviness.

Color.—Must be uniform, neither too light nor too high.

Salt.—Well dissolved, thoroughly worked in, not too high nor too light.

Package.—Good and sound as required in classification.

Extra firsts.—Shall be a grade of butter scoring 91 points or higher.

Flavor.—Must be fresh, clean, and sweet, and fairly clean if held; all other requirements same as extras.

Firsts.—Shall be a grade of butter scoring 87 points or higher.

Flavor.—May be faulty but must be fairly good.

Body.—Fairly good grain and texture.

Color.—Fairly uniform.

Salt.—Not unreasonably high or light.

Package.—Good and sound as required in classification.

Seconds.—Shall be a grade of butter scoring 80 points or higher.

Flavor.—May be unclean.

Body.—Must be fairly smooth boring.

Color.—May be irregular or mottled.

Salt.—May be irregular, high, light, or uneven.

Package.—Same as required in firsts.

Thirds.—Shall be a grade of butter scoring 75 points or higher.

Flavor.—May be off, old, or strong tops and sides.

Body.—May not be smooth boring.

Color.—Mixed or streaked.

Salt.—Irregular.

Package.—Miscellaneous.

Packages to be used.—Creamery tubs, hardwood, about 60 pounds (for extras shall be standard white ash with wood hoops). All other style of package must be specified.

GRADES OF CREAMERY BUTTER ESTABLISHED BY THE SAN FRANCISCO WHOLESALE DAIRY PRODUCE EXCHANGE FOR THE SAN FRANCISCO MARKET.

(The grade is not determined by the score alone.)

Extras.—Extras shall consist of the highest grade of butter.

Score.—Score shall average 93 points or higher for creamery or dairy; 90 per cent shall be up to the following standard, the balance shall not grade below "firsts."

Flavor.—Flavor must be quick, fine, fresh, and clean, if of fresh make, and good, sweet, and clean if storage stock.

Body.—The body must be firm and solid with perfect grain or texture, free from salviness.

Color.—Color must be uniform, neither too light nor too high; good straw-color standard.

Salt.—Salt must be thoroughly dissolved; not too high or too light salted.

Package.—Packages must be good, uniform, sound, and clean, and free from labels, brands, or stencil marks.

All fresh California butter, either squares or solid packed, grading "extras," to grade as such and be a good delivery when sold under the spot call, and in the absence of any agreement to the contrary, shall be packed, when in squares, in new, white wood 60-pound cases, parchment lined; and when solid packed, shall be packed in cubes, whose inside dimensions shall be $12\frac{1}{4}$ by $12\frac{1}{4}$ by $13\frac{1}{2}$ inches, parchment lined, and the cubes shall weigh not less than 63 pounds nor more than 68 pounds net weight.

Prime firsts.—Prime firsts shall be a grade just below extras scoring 90 points or higher for creamery or dairy; 85 per cent shall be up to the following standard, the balance shall not grade below "firsts."

Flavor.—Flavor must be good, sweet, clean, and fresh for all current make, and good, sweet, and clean for held. All other requirements shall be the same as for "extras."

Firsts.—Firsts shall be a grade just below prime firsts, scoring 87 points or higher for creamery or dairy; 85 per cent shall be up to the following standard, the balance shall not grade below "seconds."

Flavor.—Flavor must be good, sweet, clean, and fresh for all current make, and good, sweet, and clean for held. All other requirements shall be the same as for "extras."

Seconds.—Seconds shall consist of a grade just below firsts. Score must be 80 points or higher for either creamery or dairy.

Flavor.—Flavor must be fairly good and sweet.

Body.—Body must be solid boring. If ladles, must be 90 per cent solid boring.

Color.—Color must be fairly good, although it may be irregular.

Salt.—Salt may be irregular, high, or light salted.

Package.—Packages must be good and sound, but may be second hand.

Thirds.—Thirds shall consist of a grade just below seconds. Score must average 70 points or higher.

Flavor.—Flavor must be reasonably good, may be strong on tops and sides.

Body.—Body must be fair boring if creamery or dairy and at least 50 per cent bore and full trier if ladles.

Color.—Color defective, mixed, or streaky.

Salt.—Salt irregular.

Package.—Package fairly uniform.

MARKET INSPECTION OF CREAMERY BUTTER.

In applying the grades established by an exchange, an inspector is employed or some person is appointed to make the inspections. In making an inspection a portion of the tubs in the lot is examined. The rules of the New York Mercantile Exchange provide that samples shall be drawn from each lot of "one mark and invoice," meaning one shipment from a single creamery, as follows:

Inspect 5 tubs from lots of less than 25 tubs.

Inspect 8 tubs from lots of 25 to 50 tubs.

Inspect 15 tubs from lots of 50 to 100 tubs.

Inspect 20 tubs from lots of 100 or over.

The rules of the Chicago Butter and Egg Board provide for the sampling and inspection of 5 tubs from lots of less than 50 tubs, and 10 tubs from lots of 50 to 100 tubs. Whenever the butter is quite irregular in quality the inspector may increase the number of samples until he is satisfied with his score for the lot. As the grade of a lot of butter usually is determined by the inspection of less than 20 per cent of the tubs, it is possible that the tubs inspected may not truly represent the average grade of the entire lot. The particular tubs in-

spected may be those of a churning of a lower or higher grade than the other tubs. It would be possible to avoid this if creameries would give each churning a consecutive number, and number the tubs of each churning accordingly. (See par. 6, p. 33 of Iowa State brand requirements.) In this way one tub from each churning could be inspected. This practice would also be a convenience to receivers and buyers in selecting tubs of the same quality or of a single churning.

DUTIES OF OFFICIAL MARKET INSPECTORS.

Most of the butter sold on the "call" is bought subject to official inspection, and in such sales the certificate of inspection is delivered to the buyer with the butter. When requested to do so the inspector also may certify to the grade of butter received by members of the exchange from creameries or sold privately by them. In some markets butter purchased for export, for the Government, or for private, municipal, or State institutions must bear the official stamp of the inspector. In trading between members of the exchanges, a certificate is issued but the packages are not stamped unless it is requested.

In some markets the inspector is regularly employed by the exchange, while in others one of the members of the exchange may be appointed to serve as inspector, since there are but few sales on "call" and inspections are rather infrequent.

Most of the butter is accepted from creameries by the wholesale receivers without an official inspection. Even in the market distribution of the butter it is largely a matter of bargaining between the salesman and the buyer. The receiver or buyer is the judge of the quality, and his inspection is spoken of as being "over the trier." If the price and quality are satisfactory, official inspection is unnecessary. Official market inspection of shipments from creameries are more frequent on a weak market or when the trend of prices is lower than on a firm market when prices are advancing. Such a practice has been criticized, and it has been proposed that the State creamery associations should maintain inspectors on the larger and more important markets. It has also been suggested that the Federal Government might maintain an inspection service on the principal markets and at points of concentration. Such a service would require the promulgation of Government grades for butter.

BUTTER QUOTATIONS.

Butter quotations are usually intended to serve as an index of the wholesale market value of certain grades of butter. Formerly the wholesale trade organizations exerted a considerable influence upon butter market quotations through quotation committees. In most markets at present the quotations are determined by market-reporting

agencies. The methods employed in arriving at the quotations vary somewhat in the different markets. It is the usual custom for a market reporter who is acquainted with the wholesale receivers and jobbers on the market to interview these dealers and obtain current information from them regarding the condition of the market, buying and selling prices of the various grades of butter, and the general movement of receipts. He also attends the meeting of the exchanges where he interviews members of the wholesale trade organization and notes the offers and bids on the "call." With this general information he is able to make a report of the market prices of butter which when published becomes the market quotation.

INFLUENCE OF EXCHANGE TRADING ON QUOTATIONS.

In a few markets the quotations for butter are established in accordance with the method just described, and the exchange trading has a considerable influence on the quotations. The sales on the "call" represent a very small percentage of the total receipts. Therefore it is apparent that the market reporter should be able to detect irregularities in the offers and bids in order to establish a quotation which reflects the actual market value. When market values are continually underquoted, the paying of premiums over quotations usually results. Exchange trading, therefore, which reflects the true market value of butter, must be free from manipulations.

That the New York Mercantile Exchange, the Chicago Butter and Egg Board, the Elgin Board of Trade, and the San Francisco Wholesale Dairy Produce Exchange have a widespread influence on the price and movement of creamery butter is generally recognized. The New York Mercantile Exchange meets at 10 each morning, eastern time; the Chicago Butter and Egg Board at 9.30, central time; and the Elgin Board about 12 m. on each Saturday.

Various methods of effecting sales on "call" are employed. Usually the offerings are numbered, and the bidder stipulates the number of the lot for which he is bidding. A sale is effected whenever a bid and offer of the same grade coincide. During the "call" the offers, bids, and sales are usually posted on the blackboard or "call" board.

THE BASIS FOR MARKET QUOTATIONS.

The true basis for a market quotation is the price at which the majority of the sales of a definite grade are made. By majority of the sales is implied the sales made under the free influence of the law of supply and demand. The greatest difficulty in establishing accurate market quotations at the present time is to obtain the price

at which actual sales of butter of a definite quality are made. Present quotations are largely estimates and approximations of market values.

The following reports of the butter markets at Chicago and New York were taken from the sources given and indicate the information which is considered of interest and value to producers and distributors of butter. It may be well to note that butter prices were at the climax for the season at the time these reports were made, having reached 38 cents at New York and 36½ cents at Chicago. Butter was mostly out of storage and current receipts in ready demand. Lighter buying by the retailers, attributed to curtailed consumption due to the current prices, had resulted in an unsettled feeling and slightly lower prices ruled during the following two days. The range between the lower and better grades was the narrowest for the season. The statements which are here presented in italics deserve especial notice.

NEW YORK, WEDNESDAY, MARCH 22, 1916.

(From the Producers' Price-Current.)

Butter.

	This week.	Last week.	Last year.
Receipts, Monday, pkgs..	5,041	5,268	4,365
Receipts, Tuesday.....	11,241	12,658	11,366
Receipts, Wednesday....	9,834	8,819	8,948
Total.....	26,176	26,745	24,679

The present supply of fresh creamery is barely equal to current wants, and the market maintains a firm position. There is a loss of trade in some directions, due to the advanced retail prices, but receipts from the usual sources of supply are not increasing materially as yet. Another carload of California butter in to-day, but not available at the present writing. Further shipments in transit, and this may relieve the situation somewhat. Transactions on 'Change this morning included seven lots of 25 tubs each, creamery extras, at 38¢. Open business was very generally at that price, but the feeling was strong enough to give sellers some advantage, and it did not always require inspected goods to go at that rate. The higher

CHICAGO, THURSDAY, MARCH 23, 1916.

(From Daily Trade Bulletin.)

The receipts at Chicago (not including through shipments) for the days mentioned were as follows:

Butter.

	This week.	Last week.	Last year.
	<i>Tubs.</i>	<i>Tubs.</i>	<i>Tubs.</i>
Monday.....	9,840	8,079	9,794
Tuesday.....	8,675	6,832	8,927
Wednesday.....	8,387	7,908	8,366
Thursday.....	4,805	4,843	5,649
Total.....	31,707	27,662	32,736

A steady feeling exists and prices practically unchanged. New York was reported 1¢ lower.

A fair business is being transacted, and as yet the market keeps cleaned up quite closely, although receivers find they are compelled to carry over butter occasionally, as the demand is limited to buyers supplying their immediate wants, and these are not for any great quantities. Conditions are not just what they were a few days ago, when butter was taken up on arrivals and the price was no object. Now buyers hesitate and figure on what will do them the best, and

scoring lots are still absorbed mostly by regular trade; anything free to be sold brings $38\frac{1}{2}$ @ 39ϕ . Fresh firsts and seconds have quick sale, the former at $36\frac{1}{2}$ @ $37\frac{1}{2}\phi$ and the latter at 34 @ 36, with comparatively few lots to be had below 35ϕ . Unsalted creamery moving out very satisfactorily. Storage creamery continues in active demand, and the small available stock is fast passing out of first hands. Extras are firm at $35\frac{1}{2}$ and 36ϕ , several sales reported at the top figure, and other grades range from 33 and 35ϕ .

Creamery, extras (92 score, per lb.....	38 @
Creamery (higher scoring lots)	$38\frac{1}{2}$ @ 39
Creamery, firsts (88 to 91 score)	$36\frac{1}{2}$ @ $37\frac{1}{2}$
Creamery, seconds (83 to 87 score)	34 @ 36
Creamery, thirds.....	32 @ 33
Creamery, unsalted, fancy..	39 @ 40
Creamery, unsalted, prime to choice.....	$37\frac{1}{2}$ @ $38\frac{1}{2}$
Creamery, unsalted, common to good.....	34 @ 37
Creamery, held, extras....	$35\frac{1}{2}$ @ 36
Creamery, held, higher scoring	
Creamery, held, firsts....	34 @ 35
Creamery, held, seconds....	$31\frac{1}{2}$ @ $33\frac{1}{2}$
Creamery, held, thirds....	30 @ 31

are taking the undergrades, or something a little cheaper than the highest priced goods. High prices have curtailed consumption somewhat, and some jobbers or cutters, while not receiving direct any more butter than they usually obtained, have a little surplus occasionally, for which they must find outside sale, simply because their outlet has been reduced. Dealers in most instances are anxious to keep sold out, and, while adhering to the market value, there is a more or less nervous feeling noticeable.

A small car of butter was received from California. It is put up in boxes of about 66 lbs. The quality was pronounced very fine and quotably about 36ϕ .

A small consignment of butter is expected to be received from New Mexico to-day or to-morrow.

Storage butter in good demand. June Extras are salable at 34 @ $34\frac{1}{2}\phi$; some fancy, special lots are held above. Firsts are quotable at 33 @ $33\frac{1}{2}$. It is claimed by dealers there is nothing to be had under about 32ϕ .

Extras in fresh creameries met with a fair demand, and it is not easy to secure desirable makes. They are quotable at $36\frac{1}{2}$, and occasional small lots of special brands brought a slight premium.

Extra firsts which grade 91 points and up are salable at 36ϕ .

Firsts in fresh creameries are quotable within the range of 34 @ $35\frac{1}{2}\phi$. Anything sweet and suitable for table use is picked up readily.

Seconds in creameries are very scarce. Can not hear of any transactions, and quoted nominally about 31 and 32ϕ .

Creamery extras, fresh, per lb	$36\frac{1}{2}$
Extra firsts.....	36
Firsts	34 @ $35\frac{1}{2}$
Seconds	31 @ 32

PUBLICATION OF BUTTER QUOTATIONS.

New York.—The New York butter quotation is published in The Producers' Price-Current, a daily publication issued by a market-

reporting agency. This quotation is established by them and is used quite generally by the creameries of Minnesota, Iowa, and other States shipping to the New York market.

Chicago.—The Chicago butter quotation is published in the Daily Trade Bulletin, which is devoted to the produce markets. This quotation is used quite extensively by Iowa, Wisconsin, and other creameries selling their butter on this market.

Philadelphia.—At the close of each daily meeting of the Philadelphia Produce Exchange a vote is taken by the members upon the condition of the butter market and the quotation for that day. This price is marked upon the board and becomes the market quotation. This quotation is published in the daily and trade papers by authority of the exchange as the official quotation. It is used as the basis of sales to retailers and also for purchases of butter from nearby creameries.

Boston.—The Boston butter quotation which is used as a trading basis between New England creameries and the Boston butter dealers is published in the weekly market report issued by the Boston Chamber of Commerce. A committee of the Chamber of Commerce establishes a quotation on Wednesday of each week. A daily quotation is also published by the Boston Fruit and Produce Exchange in the form of a mimeographed sheet, which is distributed to its members and serves principally as a guide for local trading.

San Francisco.—The butter quotation at San Francisco is established by the San Francisco Wholesale Dairy Produce Exchange through the bids and offers on the "call," and is published by the Daily Commercial News as the official quotation for that territory. The markets at Los Angeles, Portland, Seattle, Spokane, and Salt Lake City are influenced to some extent by the San Francisco quotation.

THE ELGIN QUOTATION.

The Elgin quotation is established by the Elgin Board of Trade at Elgin, Ill. At one time this town was the center of the creamery industry of northern Illinois, which embraced a territory known as the Elgin District. The creameries throughout this territory inaugurated a practice of offering their butter for sale to buyers at meetings of the Elgin Board of Trade, which were attended by butter dealers from Elgin, Chicago, and other cities. For a number of years the quotation established for creamery butter by the Elgin board was the basis at which creameries generally sold their butter and also purchased their butter fat. Very little creamery butter is produced within the territory surrounding Elgin at the present time, as the sweet cream and milk supply is contracted for by condenseries and Chicago milk distributors. At present there are a few persons

who are interested in the operation of the Elgin board and every Saturday at noon they meet for the purpose of transacting a few sales, which establish a quotation for the following week. The Elgin board recognizes but one grade of butter, namely, an "extra," which is required to score 93 points. The rules of the board do not provide a penalty for the offering of butter on the board which is lower than an "extra," and the buyer may reject his purchases if he finds the butter to be of a lower grade.

Throughout Wisconsin, Illinois, Iowa, Indiana, and Ohio many creameries base the selling price of their butter upon the Elgin quotation and to some extent also the buying price of butter fat. Many distributors in Cleveland, Buffalo, Baltimore, and other cities, particularly those of the South, which formerly obtained their supplies from the Elgin district, prefer to have their purchases based on the Elgin quotation. This quotation is infrequently used as a trading basis by the large centralizing creameries.

MARKET DISTRIBUTION OF CREAMERY BUTTER.

There are various channels of trade through which butter may pass from producer to consumer. The general custom of country creameries in shipping butter to the larger markets is to consign it to the receiver or to contract with the receiver for the sale of the butter on the basis of the market quotation. Often the receivers send out field representatives who go among the creameries and solicit their output.

It is a common practice among creameries to draw a sight or demand draft against the consignee and to attach this to the bill of lading which is passed to their local bank for collection. By so doing, the creamery obtains an advance credit of \$10 to \$15 on each 63-pound tub of butter in the shipment.

The jobbers in buying from the wholesale receivers inspect the butter and buy such grades and quantities as they require for their trade. Nearly all wholesale receivers also do a jobbing business and supply retail stores. A considerable portion of a wholesale receiver's business consists of car-lot and less-than-car-lot sales to distribute in his own or in other large markets.

The tendency among the larger creameries, and to some extent also among the smaller, is to distribute directly to the retailer, by establishing branch distributing offices or by contracting with distributing agents to handle their account in a certain territory. In some cities delivery equipment is furnished the distributor by the creamery to develop the business and facilitate the distribution of the product. Some dealers have their salesmen take orders and the delivery is made later. (See fig. 14.) Others who handle private brands of print butter, also eggs and cheese, have their salesmen make

the deliveries at the time the order is taken, thus effecting very economical distribution of small orders. In some cities, old established firms use the telephone extensively in soliciting orders. Deliveries are made to the down-town stores and markets daily, and to the suburban stores two or three times a week.

DISTRIBUTORS' MARGINS ON BUTTER.

The costs of market distribution were investigated in each of the cities visited which included the larger and more important whole-



FIG. 14.—The storage of butter tends to stabilize butter prices. About one-tenth of the total annual production is placed in storage where its quality is preserved at a temperature of zero Fahrenheit or below.

sale and jobbing markets in the United States. It was found that the margins taken by butter distributors, in general depend upon the character of the business done; that is, whether wholesale or retail, and such factors as volume of business, extent of charged accounts, competition, and general conditions of the market. The wholesale receiver sells large lots usually at a margin of from one-fourth to three-fourths cent a pound with a fair average of one-half cent per pound. The jobber who distributes bulk packages or prints, employs salesmen, maintains delivery equipment, and extends credit to the retailer, usually receives from $1\frac{1}{2}$ to $2\frac{1}{2}$ cents per pound gross margin for rendering this service. The gross margin is not all net

profit, for a large amount of capital is required to conduct a wholesale or jobbing business and the expenses are considerable. (See Fig. 15.)

The margins taken by the retailer show wider variations than those for other distributors. Butter frequently is handled by some stores on a week-end day at cost, for the purpose of attracting customers as an advertising feature. The usual margin taken by cash stores and chain stores will vary from 3 to 5 cents, depending upon the ruling retail price of butter. The retailer with a small butter business, who has to maintain an expensive delivery service and carry numerous credit accounts, often takes a margin of 5 to 7 cents to cover costs and profit.



FIG. 15.—The distributing equipment of wholesalers and jobbers of butter may be quite extensive. Often salesmen use automobiles when taking orders and auto trucks or wagons are used in making delivery.

COLD-STORAGE METHODS AND FACILITIES.

A considerable amount of butter is placed in cold storage during the season of surplus production, which begins about April 1 and extends into August, when the receipts of fresh butter on the markets are larger than the requirements for the consuming trade. It is a well-recognized fact that storage of butter is an economic necessity, first, as a means of conserving its quality and, second, as a factor in equalizing the price throughout the various seasons of the year. The better grades of butter are in greatest demand for storage

purposes. Many distributors who have a regular established trade make a practice of storing butter in order to be assured of a supply during the winter season. Other dealers store large quantities of butter as a speculative investment.

The principal places of storage in the eastern United States are Chicago, New York, Boston, Philadelphia, and Omaha. Among other cities at which considerable quantities are stored are St. Paul, Duluth, Buffalo, Pittsburgh, St. Louis, Kansas City, New Orleans, and Norfolk. On the Pacific coast San Francisco, Portland, Seattle, Spokane, Salt Lake City, and Los Angeles are the principal points of storage. Owing to its geographical location, which permits easy reshipment to the East or South, Chicago is the greatest center for the storage of butter. Omaha is becoming a large storage center for butter made by the centralizing plants in that section. A temperature of zero Fahrenheit or below usually is maintained in butter-storage rooms.

REPORTS OF HOLDINGS IN STORAGE.

There are approximately 50 cold-storage warehouses that are members of the American Warehousemen's Association which report at the close of each month the amount of butter and eggs in their storages. This report is issued by the secretary of the association. These warehouses are believed to carry approximately 50 per cent of the total butter in storage.

On August 1, 1916, the Office of Markets and Rural Organization of the Department of Agriculture began to issue monthly reports of the holdings of creamery butter in storage. Information for these reports is obtained from the cold-storage warehouses on blanks furnished by the department. Statistics of the cold-storage holdings of butter in 1914 indicate that approximately 18 per cent of the butter placed in storage is received into storage in May, 33 per cent in June, 23 per cent in July, and 7 per cent in August, or during these four months 81 per cent of the butter stored is delivered into storage. Deliveries out of storage were more gradual, approximately 11 per cent being removed in August, 8 per cent in September, 9 per cent in October, 12 per cent in November, 15 per cent in December, 11 per cent in January, 9 per cent in February, 11 per cent in March, and 5 per cent in April. The deliveries out of storage during each of eight months (September to April, inclusive) exceed the receipts into storage, therefore the period of storage for various lots is variable. The average length of storage is approximately 6.2 months.

Legislation in regard to the cold storage of butter differs in the various States. Some States require that the packages be stamped

with the dates the butter is placed in storage and removed from storage, while others require only the date of removal. Many States have no such requirements.

THE RATES FOR STORAGE OF BUTTER.

The rates for storage of butter vary in different cities and with different storages. The following schedule is found to prevail with many cold-storage companies:

- 12½ cents per hundredweight per month for less than car lots.
- 10 cents per hundredweight per month for car lots.
- 25 cents per hundredweight per month for small lots stored for 30 days or less.

The customary rate with small storages is one-fourth of a cent per pound per month.

FINANCING OF STORAGE OPERATIONS.

Formerly it was customary for storage operators to negotiate loans on butter through banks, but now many cold-storage houses handle the loans themselves and hold the warehouse receipt as collateral security. The usual interest rate charged on loans is 6 per cent. The charges for insurance range from \$4 to \$15.50 per \$1,000 valuation, depending upon the construction, location, and equipment of the building. These are based upon a yearly period and rebates are made when the butter is carried for a shorter time. The amount loaned on butter varies from 60 to 70 per cent of its value. It is often convenient for butter distributors to deal directly with a storage company in obtaining loans and insurance, and storage companies acting as agents in these lines facilitate their business and fill their rooms. They can also handle smaller accounts and make larger advances, as they have the butter in custody.

MARGINS ON STORAGE BUTTER.

The margins on storage butter depend upon a number of factors, such as the keeping quality of the butter, the marginal difference between the price paid and the market value of the butter when it is removed from storage, the costs of storage, and the expense of handling it. It is customary to estimate the carrying charges roughly at one-fourth cent per pound per month. The following statement illustrates the approximate costs for interest, storage, and insurance:

Interest on 100 pounds butter at 28 cents for six months at 6 per cent—	\$0.84
Storage on 100 pounds butter at 10 cents per hundredweight per month for six months—	.60
Insurance at rate of 42 cents per \$100 for six months—	.1176
Cost per 100 pounds for 6 months—	\$1.5576
Cost per 100 pounds per month—	.2596

BRANDS AND TRADE-MARKS FOR BUTTER.

Within recent years there has been a growing tendency to establish private brands and trade-marks for butter. The adoption of a private brand and the registration of it gives a distributor or creamery a basis for working up a special demand or trade, also for carrying on an advertising campaign. Designs and names which are intended as trade-marks may be registered in some States, and with the United States Patent Office at Washington, D. C.

STATE BRANDS FOR BUTTER.

Several States have adopted State brands for butter, the purposes of which have been varied. Oregon and Washington some years ago adopted a system of State brands which was intended to be used



FIG. 16.—Trade mark for "A 1" grade of Minnesota State Brand Butter.

only on butter produced within the State. More recently the States of Minnesota, Iowa, and Michigan have provided for State brands which are intended to convey a guaranty of purity and quality.

STANDARDS FOR STATE BRAND BUTTER.

Minnesota was the first State to pass a law providing for the use of a State brand by butter and cheese factories when certain conditions are complied with. (Minnesota general laws of 1913, ch. 366.) The Minnesota State brand is patterned to some extent after the requirements of the Government export brand of Denmark, known as the "Lur" brand. The designs adopted for the two Minnesota brands are alike except in the lettering (A1) or (B). (See fig. 16.) The requirements for the use of the "A 1" brand are more strict than for the "B." Following are the requirements for the use of the A1 brand, as published in the Fifteenth Biennial Report, 1914, p. 23, of the Minnesota Dairy and Food Commissioner.

Score of butter or cheese to be 94 nine times out of twelve in 1 year. Score of butter or cheese can never be below 93. Factory to score 90 or better. Sanitary machinery, piping, and equipment. Score of 94 for the butter made 15 days prior to application for license. Farm dairy to score 60 points or better according to score card provided by dairy and food commission. Cows tested for tuberculosis 6 months previous to issuing license and every 2 years thereafter. Cream to be pasteurized. Cream must be received sweet and test less than 0.2 per cent acid. Use of neutralizers in cream not permitted. When a license is granted a list of the patrons must be furnished the dairy and food commissioner, with address of each, and statement that cows have been tested for tuberculosis. Factory must report number of pounds of butter manufactured each month. Brand is to be used only at factory.

The rules for grade B permit a lower score and the use of milk and cream from cows which have not been tested for tuberculosis.

The State of Iowa (Supplemental supplement, Code of Iowa, 1915, section 2515-f) in adopting a State brand or trade-mark (see fig.



FIG. 17.—Trade-mark for Iowa State Brand Butter.

17) for Iowa butter placed it in charge of an executive committee of five members, consisting of the president of the Iowa State Dairy Association, the president of the Iowa State Buttermakers' Association, the dean of the division of agriculture of the Iowa State College of Agriculture and Mechanic Arts, the professor of dairying of the same institution, and the dairy and food commissioner of the State of Iowa, who have control of the use of the trade-

mark under such rules as may be considered necessary. The following rules and regulations governing the use of the Iowa butter trade-mark were issued in Bulletin No. 16 of the Iowa dairy and food commission, December, 1915:

1. Butter sold under the trade-mark shall be manufactured in a creamery which meets the requirements of the Iowa sanitary law. Such creameries shall obtain a score of 85 or above, 100 being perfect, scored in accordance with the Iowa State score card for creameries.

2. The butter shall obtain a score on the quality of not less than 93 points, 100 being perfect, on 75 per cent or more of the scoring. A creamery obtaining a score on butter below 92, or a creamery that has more than 25 per cent of its scoring below 93, shall forfeit its right to the use of such trade-mark until such time as the creamery is again in a position to meet the necessary requirements.

3. All butter marked with the Iowa State mark shall comply with the Iowa State standards and contain not less than 80 per cent of butter fat, and shall contain less than 16 per cent of moisture. No preservative, neutralizer, or

adulterant shall be added to butter or to the cream from which the butter is to be manufactured.

4. Butter sold under said mark shall be manufactured from cream which has been pasteurized, either in the form of milk or cream. Pasteurization shall consist in heating the milk or the cream to a temperature of not less than 140° F. and holding it above 140° F. for a period of not less than 20 minutes, or heating the milk or cream to a temperature of not less than 180° F. when flash is applied.

5. If the butter is solid packed in tubs, the tubs shall bear the Iowa State mark on two opposite sides, the marks shall be placed immediately below the upper hoop or hoops, said mark to be 3 inches in diameter. In addition to the markings as stated, the top surface of the butter shall bear an imprint of the said mark, this imprint to be 5 inches in diameter and the imprint into the butter shall be from one-sixteenth to one-eighth of an inch in depth. Butter in boxes either solid packed or in print shall bear similar markings on both ends of the boxes as those placed on the outside of tubs. A similar imprint shall be made into the butter if solid packed.

6. The date of manufacture of the butter shall be marked on the outside of the tub or box close to the State mark, in letters not less than one-half

an inch in height, the same being placed in the following manner: $\frac{12-5}{6}$

The figure 12 designates the number of the month, the figure 6 designates the day of the month, and the figure 5 designates the number of the churning on that day. Thus for the above markings the reading would be that the butter was manufactured on the twelfth month, sixth day, and was the product of the fifth churning.

7. Parchments for print butter may be marked with the State trade-mark. The size of such marking shall be 2 inches in diameter. At this time the board does not require the marking of the date on individual prints.

8. Application, in writing, shall be made to the State dairy and food commissioner, who, after having satisfied himself that the manufacturer is qualified to comply with all the requirements, will issue a permit to use the State mark and also furnish copies of the mark and necessary equipment to the applicant. No other stamp or markings shall be used unless the same shall meet with the approval of the State dairy and food commissioner.

The State of Michigan by an act of the legislature (Michigan public acts . . . 1915, public act No. 53) provided for a Michigan State brand butter commission, which has authority to adopt rules, regulations, and specifications for Michigan State brand butter. The commission in its bulletin No. 1 established the following provisions, which became effective January 1, 1916:

SECTION 1. Applications.—Any person, firm, or corporation desiring to use the brand or label provided for in the above-named act, in the manufacture or sale of butter, shall make written application on blanks to be furnished by the dairy and food department, for a license therefor to the dairy and food commissioner at Lansing, which application shall describe by location and name the creamery or factory in which such butter is to be manufactured, and give such other information as may be required. A license shall be granted to such person, firm, or corporation to use such brand or label at the factory described in the application if on investigation by the dairy and food commissioner, his deputy or duly authorized assistants, it appears that all the

provisions of act No. 53, P. A., 1915, and the rules, regulations, and specifications of the commission have been complied with. Such license so granted may be revoked by the said commissioner if any of the provisions of the above-named act, or of the rules, regulations, and specifications of the commission have not been complied with. Such license so granted shall not be transferable.

SEC. 2. *Labels*.¹—As provided in section 4 of the above-named act the dairy and food commissioner will furnish to those entitled to the use of the brand or label such labels or stamps or other means of imprinting such trade-mark or brand upon the manufactured product or the receptacles containing the same.

SEC. 3. *Samples*.—Any person, firm, or corporation to whom the use of the brand or trade-mark has been granted shall, whenever called upon, submit a sample or samples of the butter manufactured by any such person, firm, or corporation for scoring, grading, or examination to the dairy and food department.

SEC. 4. *License*.—The license referred to in the first section of these rules, regulations, and specifications will be and is issued on the express condition that the person, firm, or corporation to whom such license has been granted shall comply with the following:

(a) *Sanitation*.—Maintain proper and satisfactory sanitary conditions in the plant in which the butter is made, and proper and satisfactory sanitary surroundings.

(b) *Raw material*.—That no milk or cream be received which is to be made or is made in butter, upon which the Michigan brand or trade-mark is to be used, that will not comply with the provisions of act No. 222, P. A., 1913.

(c) *Pasteurization*.—That the butter shall be made from milk or cream that has been pasteurized at a temperature not less than 145° F., and shall be held at that temperature for 20 minutes, or to a temperature not less than 170° F. if not held.

(d) *Grade of butter*.—That the butter shall be of the grade of "commercial extra" (92-93) score, or higher, for not less than 75 per cent of the scorings on samples collected by the dairy and food department, and while the butter is fresh. "Fresh" butter being here defined as butter less than 30 days old from the date made and providing same has been held at a temperature lower than 55° F. after being made. In no instance shall the butter score less than 91 points—100 being perfect—while "fresh," according to the above definition.

(e) *Composition*.—All butter upon which the State trade-mark is to be used shall contain not less than 80 per cent fat, and shall contain less than 16 per cent water; the butter shall have a uniform salt content ranging from not less than 2½ per cent or more than 3¼ per cent.

(f) *Color*.—The color shall be of the highest June shade, uniform, and of the same shade at all seasons.

(g) *Adulterants*.—No preservatives (except pure common butter salt), neutralizers, or adulterants shall be added to the milk or cream from which such butter is made and which is to be sold under the Michigan trade-mark.

(h) *Creamery plant score*.—The creamery or plant in which the butter is made shall receive a minimum score of 85 points—100 being perfect—embodying the following: (1) General appearances of premises, (2) floors, (3) drainage, (4) refrigeration, (5) machinery, (6) water, (7) raw material.

(i) *Reports*.—Make a monthly report to the dairy and food department on blanks to be furnished by said department not later than the last day of the month following.

¹ A revised trade-mark for Michigan State brand butter was being designed when this bulletin went to press.

(j) *Labeling*.—Label and mark all receptacles containing butter upon which the State trade-mark is to be used in accordance with the special instructions that will be issued to every creamery to whom a license has been granted with such labels, stamps, or other means of imprinting the trade-mark, or such other information as may be required by the dairy and food department.

(k) *Thermostat*.—Install in connection with all pasteurizing machinery a thermostat or recording thermometer, and file all charts for inspection or submit same, if requested, to the dairy and food department.

(l) *To whom shipped*.—Whenever a creamery that has been granted a license to use the State trade-mark changes its market or outlet for its product it shall promptly advise the dairy and food department of such change, and otherwise keep the department fully informed with regard to whom their butter is shipped or sold.

(m) *Change of butter makers*.—Whenever a change of butter makers is contemplated at any creamery using the Michigan State butter brand trade-mark, and before such change is made, the dairy and food department shall first be advised. If a change is made without the consent of the department the right to use the brand or trade-mark shall and will at once be revoked, until such time as it takes for the new butter maker to demonstrate that he is competent to make the grade of butter required under these rules, regulations, and specifications.

ADVERTISING AND SALESMANSHIP.

Advertising and salesmanship are two important factors in the successful marketing of a product. Advertising has been defined as "silent salesmanship," and there is no doubt that judicious and appropriate advertising has a very suggestive and often convincing influence upon the customer, and when properly used may greatly increase the demand for a product. The results obtained from advertising campaigns made by the large creameries and distributors are evidence of their value. Among the various methods employed are advertisements of private brands of butter in newspapers, on street-car signs, bill boards, retail show cards, and demonstrations at retail stores, food shows, and by house-to-house canvassing.

Salesmanship is the art of merchandising and is the basis of successful marketing. Its importance often has not been appreciated by the country creameries, and their butter has been obliged to compete not only against the products of other creameries and the manufacturers of butter substitutes, but also against the salesmanship employed in pushing the sale of these branded and trade-marked products. In a business with a selling organization it is generally recognized that salesmanship gets business, while service, quality, and price hold it. In marketing the products of a small country creamery, which does not have a private brand and in which the identity of the manufacturer of the product is lost in the wholesale distribution of it, it is impossible for a creamery to employ either advertising or salesmanship in the ultimate distribution. With selling organizations for distributing private brands or State brands it is

different, and both advertising and salesmanship may be employed effectively. It is highly important in marketing a branded product that a certain standard of quality be maintained in the product, that a distinctive brand be adopted, and a sanitary and attractive package be used.

SUMMARY.

A knowledge of the various market requirements, marketing methods, and marketing facilities is essential for the successful marketing of creamery butter.

Particular attention should be given to the market requirements as regards quality of butter and size and style of packages. Critical markets require a clean-flavored, firm-bodied, well-made piece of butter for which they pay the highest prices. Butter of inferior quality is discriminated against by critical buyers and usually sells at prices considerably below the better grades.

The use of neat and attractive containers, standardized to a uniform size and style, is highly desirable both for local and foreign markets. Carelessly packed butter has not only a poor appearance but also usually brings a lower price.

The branding of bulk butter packages (tubs and cubes) with the gross, tare, net weight, and churning number greatly facilitates the handling and inspection of butter in the market.

The use of consumers' packages for butter is increasing. A standardization of these, particularly the cartons, is especially desirable.

Market grades for butter have been established by a number of wholesale produce organizations. While these conform quite closely to a uniform standard it is generally conceded that butter which will pass in some markets for a certain grade may be classed differently in another, owing to a different standard of quality which the butter inspector may use.

The employment of butter inspectors and the maintenance of market inspection is at present provided in the wholesale markets by the organizations of wholesale butter distributors. It has been suggested that the promulgation of Government grades for butter and the maintenance of a Federal inspection service would facilitate market distribution and the establishment of more accurate quotations on creamery butter.

Quotations for butter are determined in most markets by market-reporting agencies. Among the market quotations which have the widest trading influences are those established at New York, Chicago, and Elgin, Ill., and San Francisco.

The distribution of butter in the larger cities is generally effected by wholesale distributors commonly termed wholesale receivers or

jobbers, who supply the retailers, hotels, and restaurants. The gross margins taken by butter distributors depend upon a number of factors, such as kind of business, volume of business, extent of charge accounts, competition, and general market conditions.

Approximately one-tenth of the market receipts of butter is placed in public cold storage. Chicago, because of its location, is considered the most important place for the storage of butter. The cost of financing and handling butter in storage is approximately one-fourth cent per pound per month.

Regular, scheduled refrigerator rail service is provided for butter in the more highly developed dairy sections. Express service often is employed for shipping to near-by markets and may be used in combinations with refrigerator freight service in reaching the more distant markets. Cooperation among creameries has proved of value in obtaining and using refrigerator service where creameries are located in close proximity to each other.

State brands for butter which creameries are permitted to use when they have complied with State requirements have been adopted by Minnesota, Iowa, and Michigan. They are intended to convey a guaranty of purity and quality in the butter which will be of mutual benefit to both the producer and the consumer.

The establishment of brands is essential for effective advertising or in retaining the identity of the manufacturer of a product. Appropriate advertising and salesmanship are also two vital factors in successful market distribution. In marketing a branded product it is highly important that a sanitary and attractive package be used and that a certain standard of quality be maintained.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 457

Contribution from Office of Markets and Rural Organization
CHARLES J. BRAND, Chief



Washington, D. C.

November 24, 1916

RELATION BETWEEN PRIMARY MARKET PRICES AND QUALITIES OF COTTON.

By FRED TAYLOR, *Cotton Technologist.*

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INTRODUCTION.

Producers of cotton have claimed for years that certain markets have discriminated against their product and that frequently within the same market intrinsic worth was disregarded and cotton was purchased on averages, all grades bringing the same price. That such a system works to the detriment of the farmer who exercises care in producing and harvesting his crop is generally admitted. To discover, if possible, whether there was any foundation for such reports the Department of Agriculture in 1912-13 conducted a survey of Oklahoma¹ to secure accurate information as to the exact conditions under which the farmer of the western belt marketed his cotton.

So many interesting and unusual conditions were revealed by this survey that the Office of Markets and Rural Organization started an investigation in the season of 1913-14 to cover the entire cotton belt, for the purpose of ascertaining the manner in which cotton is handled

NOTE.—The survey here described, which should be of interest to all who are connected with the cotton industry, was supervised by Fred Taylor, Cotton Technologist; and the grading and stapling was done by D. C. Griffith, Investigator in Cotton Marketing; J. G. Martin, Investigator in Cotton Marketing; and R. W. Murray, formerly Assistant in Cotton Marketing. The period covered by this study was prior to the date when the cotton futures act became effective.

¹ Sherman, W. A., Taylor, Fred, and Brand, Charles J. Studies of Primary Cotton Market Conditions in Oklahoma, U. S. Department of Agriculture, Bulletin No. 36, 1913.

and marketed in the various sections of the South. Seventy-three towns in North Carolina, South Carolina, Georgia, Alabama, Mississippi, Louisiana, Arkansas, Oklahoma, and Texas, for the most part sections growing cotton of short staple, were covered by this survey. Every effort was made to discover the facts as they existed in the various marketing centers, as a basis for improvement, since little improvement is possible without a full understanding of the exact conditions under which cotton is marketed. Special attention was given to grade, to see if (and to what extent) cotton was purchased according to the accepted standards and differences existing at that time or whether it was bought on a daily average price. Special effort was made to determine whether staple was a factor in pricing the farmer's cotton or whether cotton was sold without regard to variations in length of staple. Comparisons were made between prices paid for cotton of the same grade and staple on the same day in different markets. In the course of the investigation 38,000 representative samples were secured from 73 markets in 9 different States.

METHOD OF INVESTIGATION.

Men who were experienced in the cotton business were appointed in the various markets covered by this survey. They were instructed to begin sampling as soon as cotton began to move freely and to send in 50 samples each week. Information as to the date of sale, name of seller, and price received accompanied each sample. These samples were carefully wrapped, placed in a mail bag, and shipped to Washington. The grading and stapling was done by cotton experts connected with the Office of Markets and Rural Organization. The same experts handled the entire lot of samples, thus securing a certain uniformity in the classing. When the classing was finished, the results were compiled and entered in the files of the Office of Markets and Rural Organization.

AVERAGE PRICES OF COTTON BY MONTHS FOR THE STATES COVERED IN THE SURVEY.

In order to compare prices paid for cotton throughout the Cotton Belt, the average price for each grade was obtained by months for each State. This was done by taking all of the samples from the grades Strict Good Ordinary, Low Middling, Strict Low Middling, Middling, Strict Middling, Good Middling, and Strict Good Middling, as practically all of the crop fell within these grades. By making this selection for each State, it is safe to assume that the figures fairly represent the average for the season.

TABLE 1.—Average prices of cotton for each State, by months, for the same grade and staple.

State.	Strict Good Ordinary.	Low Mid- dling.	Strict Low Mid- dling.	Mid- dling.	Strict Mid- dling.	Good Mid- dling.	Strict Good Middling.
<i>October.</i>							
	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>
Mississippi.....	13.05	12.99	13.33	13.39	13.30	13.36	13.32
Arkansas.....	12.00	12.38	12.67	13.05	13.20	13.66	15.08
Louisiana.....	11.92	12.18	12.62	13.40	13.70	14.25	13.91
Texas.....	10.18	11.50	12.23	12.83	13.26	13.03	12.67
Oklahoma.....	11.31	12.06	12.52	12.91	13.14	13.21	13.36
North Carolina.....	12.99	13.00	13.15	13.24	13.57	13.54	13.50
Georgia.....	13.06	13.02	13.20	13.36	13.41	13.50	13.58
South Carolina.....	13.31	13.25	13.18	13.41	-----	13.48	13.43
Alabama.....	13.51	13.34	13.19	13.32	13.39	13.42	13.47
<i>November.</i>							
Mississippi.....	11.56	12.07	12.26	12.36	12.57	12.80	12.70
Arkansas.....	11.21	11.73	11.83	12.17	12.87	13.22	13.40
Louisiana.....	10.91	10.86	11.21	11.76	-----	-----	12.78
Texas.....	9.88	10.48	10.88	11.35	12.04	12.01	12.17
Oklahoma.....	9.95	11.02	11.56	11.91	12.16	12.45	11.68
North Carolina.....	12.06	12.44	12.38	13.18	13.25	13.32	13.50
Georgia.....	12.31	12.41	12.86	13.14	13.27	13.39	13.43
South Carolina.....	12.42	12.85	12.97	13.16	-----	13.29	13.41
Alabama.....	12.45	12.94	12.98	12.96	13.02	13.09	13.34
<i>December.</i>							
Mississippi.....	10.75	-----	11.82	12.40	12.26	12.30	12.29
Arkansas.....	10.87	10.89	11.36	11.46	11.86	12.58	12.94
Louisiana.....	10.20	10.51	11.46	11.50	11.38	13.38	13.00
Texas.....	9.11	9.09	10.16	10.65	10.96	11.31	-----
Oklahoma.....	9.40	9.75	11.00	10.76	10.80	12.63	12.00
North Carolina.....	10.90	11.13	12.00	13.25	12.13	13.15	13.13
Georgia.....	11.35	11.66	12.16	12.66	12.79	12.86	12.95
South Carolina.....	11.19	12.10	12.43	12.44	-----	12.71	13.00
Alabama.....	11.59	12.02	12.14	12.35	12.46	12.54	12.49

A close study of Table 1 should prove of interest. In a general way this table indicates that the cotton was sold with some regard to grade, for, with a few variations, the price advanced with the grade up to Middling. But this was not true in all cases, for it will be seen that for October in Alabama Strict Good Ordinary cotton averaged 13.51 and Strict Good Middling 13.47. While the latter grade sold for 20 cents less per bale than the former, on basis of New Orleans differences, it was actually worth \$7.50 per bale more. Again, Low Middling averaged 13.34, Strict Low Middling 13.19, and Middling 13.32; and in November Strict Low Middling averaged two points higher than Middling. During the same month in South Carolina Low Middling averaged 13.25 and Strict Low Middling 13.18. Strict Low Middling was actually worth at least 25 points, or \$1.25 per bale, more than Low Middling. These variations are but a few of the many instances that might be cited, and tend to prove either that the higher grades are being priced too low or that the lower grades are bringing prices above their value, or that a combination of the two is true.

That the higher grades are not bringing their value is clearly shown by an examination of Table 1, for it will be seen that practically no grade above Middling commands a premium; but in the lower grades, Strict Good Ordinary to Middling, a gradual advance in price is

usually shown as the grade improves. This fact shows that the same condition exists over the entire belt that existed in Oklahoma in 1912; that is, the very existence of the higher grades is practically ignored. Probably nothing retards improvement in the methods of handling cotton more than this penalizing of the higher grades, for the thoughtful producer sees his product priced the same as that of his careless and indifferent neighbor, and naturally feels that there is no inducement to continue his painstaking work as long as such marketing conditions exist. In effect, it is placing a premium on the careless and indifferent farmer and penalizing the intelligent producer.

While Table 1 indicates that cotton from Strict Good Ordinary to Middling is sold on grade, it also shows that the differences as quoted on the various exchanges were disregarded. The New Orleans exchange quotations for the months of September, October, November, and December of 1913 indicate that the differences between each grade above Middling were about 25 points, or a quarter of a cent, and below Middling from a quarter to three-eighths of a cent. Table 1 will give an idea as to the range in prices over the entire belt.

The matter of freight rates must receive some consideration. While some towns, on account of water rates, enjoy certain advantages from a transportation viewpoint, the difference in rates between points is not a factor of great importance. While there may be a wide range in freight rates between Texas and Carolina points when shipment to some Carolina or eastern point is considered, the major portion of the western crop is exported and is not affected to any great extent by this difference in rates. It is well to consider that while the East has an advantage in freight rates to eastern destinations, the superiority of the staple of the western belt should more than overcome the advantages possessed by the East in transportation. However, in comparing prices it may be well to allow for an extreme variation of 50 points in order to absorb the possible difference in freight rates. Any excess over this variation would indicate that the local market was out of line. Taking, for example, Low Middling December, the range in prices is from 9.09 per pound for Texas to 12.10 per pound for South Carolina, a range of 301 points. Allowing for a variation of 50 points it is still found that Texas for that month is 250 points out of line, or \$12.50 per bale lower than South Carolina. While this instance shows the extreme range in price, many cases are recorded where differences existed between States ranging from 100 to 150 points during the same month. The widest variations usually are found between the eastern and western States.

It will be noted that the States have been divided into the eastern and western belt. Table 1 indicates that this division should be

made, as prices show clearly that there is a relationship between the States in these two sections. The western belt is almost uniformly lower in price than the eastern belt, while between Texas and Oklahoma, it is shown that the values are relatively the same. The factors that cause this difference in prices in the two sections are explained in part, as follows:

From these investigations, it appears that in the eastern belt the higher prices may be accounted for in three ways: First, and probably the most important cause, is proximity to cotton mills. Certain mills find it advantageous to control producing sections in their vicinity in so far as possible, thereby reducing competition. It is thus possible for them to pay higher prices because of low freight rates, as they see just what they are buying, and because they reduce the risk of loss in weight claims, delays, and the many other hazards incidental to buying from a distance. A second factor is probably the absence of most of the middlemen. A portion of the cotton purchased in the eastern belt, especially in the Carolinas, passes directly from the primary purchaser to the mill buyer, which enables the producer and consumer to secure profits that ordinarily are obtained by the intermediaries. A third probable reason is that in the eastern belt primary marketing conditions are superior, storage houses are more generally available, money rates are comparatively lower, and competition probably exists to a greater degree, than in the west. Then, too, the marketing of the cotton is in the hands of farmers who, through generations of training, know the approximate value of their crop, and, as a result, command a fair price for their product. If the price offered does not satisfy them they usually can store in a warehouse and, with the certificate issued, negotiate a loan, at a reasonable rate of interest, for such amounts as may be necessary to finance their business.

The results of this survey also show that in the western belt different conditions exist in the different primary markets. New sections have been developed and the virgin soil needs little fertilizer, which enables the farmer to produce cotton at a low cost except for his own labor. Low cost of production permits the underselling of the eastern sections where fertilizers add materially to the expense of raising cotton. It is a long haul to the mills, warehouses are very few, and banking rates as a rule are higher than in the eastern sections. Lack of proper facilities for housing and borrowing on the crop induce the farmer to market his crop as rapidly as it is gathered, for with no warehouse available it must be left exposed to the weather, and his experience has shown him that this is usually done at a heavy loss. Then, too, a portion of the crop is raised under the lien system, and the merchant or banker is rarely willing that the farmer should keep the cotton on the farm, as it is not safeguarded, is subject to

damage by exposure to weather conditions, and when stored in this way usually can not be utilized as a collateral for loans. For these reasons the merchant often insists that it be sold as rapidly as ginned. This rushing of cotton to the market naturally tends to depress it, and lower prices result.

VARIATIONS IN THE PRICES OF MIDDLING COTTON IN THE SAME MARKET ON THE SAME DAY IN DIFFERENT STATES IN THE COTTON BELT.

In Table 2 is shown the range in prices between bales of Middling cotton sold in the same market on the same day. In many of these markets several hundred bales of cotton were sold in a single day, and it is doubtful that in any particular case data were secured upon both the highest and lowest prices paid, on any date in any market. Therefore it is safe to assume that the range in prices shown in Table 2 is less than that which actually occurred in many primary markets.

A glance at Table 2 shows that the widely varying prices are not confined to any section of the belt, but occur in each State where cotton is grown. This condition clearly indicates that a large amount of cotton is sacrificed at a price below its real value. The extreme variation shown in the table is in Oklahoma, with a sale on October 21 in Durant of $1\frac{1}{16}$ inch cotton at 13 cents and $1\frac{1}{8}$ inch at 10.05 cents. It is safe to assume that $1\frac{1}{8}$ inch cotton is worth at least half a cent more than $1\frac{1}{16}$ inch; so, assuming that the $1\frac{1}{16}$ inch cotton sold for its full value, on this basis the $1\frac{1}{8}$ inch cotton sold for at least \$17.50 below its real value. A similar sale is recorded at Jewett, Tex., where on December 12 a bale of 1 inch cotton sold for 11 cents per pound and a bale of $1\frac{1}{8}$ inch staple sold for 9 cents, a difference of 200 points or \$10 per bale. As $1\frac{1}{8}$ inch staple is worth approximately \$5 per bale more than 1 inch, the total loss in this instance would approximate \$15 per bale. A number of such sales are recorded in Table 2.

TABLE 2.—*Variations in the price of middling cotton in the same market, the same day, in different States in the cotton belt.*

Market.	Date of sale.	Length of staple.	Price per pound.	Length of staple.	Price per pound.	Difference in points.	Difference per bale.
		<i>Inches.</i>	<i>Cents.</i>	<i>Inches.</i>	<i>Cents.</i>		
South Carolina:							
Chapin.....	Feb. 10, 1914	$\frac{3}{4}$	13.00	$1\frac{1}{16}$	12.00	100	\$5.00
Alabama:							
Huntsville.....	Dec. 4, 1913	1	12.50	$1\frac{1}{8}$	11.50	100	5.00
Troy.....	Jan. 8, 1914	1	12.50	$1\frac{1}{8}$	11.25	125	6.25
Montgomery.....	Jan. 24, 1914	$1\frac{1}{16}$	13.12	$1\frac{1}{8}$	12.12	100	5.00
North Carolina:							
Raleigh.....	Nov. 11, 1913	$\frac{3}{4}$	13.38	$\frac{3}{4}$	12.38	100	5.00
Georgia:							
Dublin.....	Dec. 19, 1913	1	12.50	$1\frac{1}{8}$	10.00	250	12.50
Moultrie.....	Oct. 22, 1913	$1\frac{1}{16}$	12.75	$1\frac{1}{8}$	11.75	100	5.00
Washington.....	Dec. 11, 1913	1	13.00	1	11.00	200	10.00
Mississippi:							
Aberdeen.....	Nov. 25, 1913	$1\frac{1}{16}$	13.00	1	12.50	50	2.50
Corinth.....	Dec. 5, 1913	$1\frac{1}{16}$	13.00	1	11.60	140	7.00
Starkville.....	Nov. 28, 1913	1	12.75	$1\frac{1}{8}$	10.10	265	13.25

TABLE 2.—*Variations in the price of middling cotton in the same market, the same day, in different States in the cotton belt—Continued.*

Market.	Date of sale.	Length of staple.	Price per pound.	Length of staple.	Price per pound.	Difference in points.	Difference per bale.
Oklahoma:		<i>Inches.</i>	<i>Cents.</i>	<i>Inches.</i>	<i>Cents.</i>		
Altus.....	Nov. 1, 1913	1	12.50	1	11.00	150	\$7.50
Atoka.....	Oct. 30, 1913	1	13.00	1 $\frac{1}{8}$	11.00	200	10.00
Do.....	Nov. 13, 1913	1	13.00	1 $\frac{1}{8}$	11.25	175	8.75
Boswell.....	Oct. 16, 1913	1	12.25	1 $\frac{1}{8}$	10.00	225	11.25
Durant.....	Oct. 21, 1913	1 $\frac{1}{8}$	13.00	1 $\frac{1}{8}$	10.05	295	14.95
Do.....	Sept. 30, 1913	1 $\frac{1}{8}$	13.85	1 $\frac{1}{8}$	11.30	255	12.75
Erick.....	Oct. 24, 1913	1	13.38	1	11.00	238	11.90
Do.....	Nov. 7, 1913	1	12.75	1 $\frac{1}{8}$	10.50	225	11.25
Texas:							
Jewett.....	do.....	1	12.50	1	10.00	250	12.50
Do.....	Dec. 6, 1913	1	11.00	1	9.00	200	10.00
Do.....	Dec. 12, 1913	1	11.00	1 $\frac{1}{8}$	9.00	200	10.00
Longview.....	Nov. 30, 1913	1	14.50	1	12.10	240	12.00
Do.....	Nov. 8, 1913	1	12.62	1	9.50	312	15.60
Sweetwater.....	Nov. 20, 1913	1	11.50	1	10.55	95	4.75
Taylor.....	Oct. 30, 1913	1	13.55	1	12.35	120	6.00
Waco.....	Oct. 23, 1913	1	13.50	1	12.00	150	7.50
Do.....	Jan. 9, 1914	1	8.50	1	7.25	125	6.25

Wide variations are shown in each State. In Raleigh, N. C., on November 11, one bale sold for 13.38 and another for 12.38, a difference of \$5 per bale; Washington, Ga., shows a difference on December 4 of \$5; Starkville, Miss., on November 28, \$13.25; Dublin, Ga., on December 19, \$12.50; Jewett, Tex., November 7, \$12.50; Huntsville, Ala., December 4, \$5; Chapin, S. C., February 10, \$5; and Oklahoma points range from \$5 to \$14.95.

Care has been used to avoid including bales which were handled as part of round-lot sales. The wide ranges in prices would seem to indicate that in many instances the prices on a great many bales must have been seriously depressed for some reason which a careful examination of the available data failed to disclose.

When such variations in prices are shown by this investigation involving two or more bales of Middling grade in any market it is apparent that gross injustices may occur in many individual cases and in the aggregate assume enormous proportions. These variations show a condition that is unfair to the producer, for it is the farmer, ignorant of the value of his crop and knowing least about marketing his product, who as a rule is called upon to submit to such practices.

"ROUND-LOT" SALES.

During the progress of this investigation information was secured on a large number of "round-lot" sales. These sales have been studied and comparisons have been made between "round-lot" sales and single-bale sales on the same day.

Practically every "round lot" came from the eastern belt, the west showing only a few, which were too small to be considered. These facts are rather typical of the two sections, as the west usually

sells in small lots as rapidly as ginned, while larger "round lots" are more common in the east.

The figures show a remarkably narrow range in prices in the eastern belt, indicating that "round lots" commanded the attention of the buyers and that competition was so keen that the producer secured the approximate value of his product. In North Carolina, South Carolina, Georgia, and Alabama on given dates the range in prices, when freight rates were considered, did not amount to as much as one-half cent per pound, and when the character of the cotton of the different sections was considered the various markets were shown to be operating on practically the same basis.

While it is difficult to make definite comparisons between "round-lot" and single-bale sales, still the figures in general clearly indicate the advantage of selling in "round lots." Although this survey did not afford opportunities for definite comparisons between "round-lot" and single-bale sales, figures of subsequent years are available. Investigations made by the United States Department of Agriculture in cooperation with the experiment station of the North Carolina Agricultural and Mechanical College in 1914-15 and 1915-16 furnish much light on the subject. During these two years data were obtained regarding 55,000 bales of cotton sold in North Carolina, and complete records were kept of each transaction. These figures show that in 1914-15 the producer received 29 points, or \$1.45 more per bale by selling in lots of 10 bales or over, and the following year he received 17 points, or 85 cents more per bale.

These data also tend to show the importance of selling cotton in uniform lots of grade and staple. Since the selling in "round lots" showed a higher price, sales in even-running lots would show equal or even higher premiums.

AVERAGE STAPLE LENGTHS AND AVERAGE PRICES FOR EACH LENGTH OF STAPLE FOR THE DIFFERENT STATES AND FOR THE ENTIRE BELT.

To the question of staple, little thought has been given by producers in short-staple sections, only the most progressive considering it of enough importance for them to devote time to the matter of general cultural improvement. The coming of the boll weevil and the resulting damage to sections producing long-staple cotton has given an impetus to the development of a longer staple in other sections, and through activities of the Federal Department of Agriculture and agencies within the States, considerable improvement has been made. Producers in some localities who a few years ago knew nothing of staple cotton are now devoting time and money to the development of a staple that is specially adapted to their particular locality. In this study attention was given to staple length to ascertain whether it was a factor in determining the price paid the producer for his

product. In considering this subject it must be remembered that this survey did not embrace the long-staple sections, and its results are not representative of conditions as they exist in those communities.

The average staple length, compiled from the 38,000 samples collected in the survey, was found to be between fifteen-sixteenths of an inch and 1 inch.

TABLE 3.—Average price for each staple and average staple length ¹ for each State.

State.	Average staple length.	Price per pound for staple of the following lengths:						
		$\frac{3}{8}$ inch.	$\frac{1}{2}$ inch.	$\frac{3}{4}$ inch.	$\frac{7}{8}$ inch.	1 inch.	$1\frac{1}{16}$ inches.	$1\frac{1}{8}$ inches.
	<i>Inches.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>
Georgia.....	0.955	12.89	13.11	12.94	13.01	13.09	13.14	13.09
North Carolina.....	.915	11.70	12.35	12.86	13.19	12.58	13.30	13.17
South Carolina.....	.93	12.59	12.52	11.70	12.89	13.11	13.27	11.53
Texas.....	.98	11.33	.....	11.28	11.05	11.19	10.87	10.94
Oklahoma.....	1.02	10.50	11.50	10.59	11.29	11.73	11.21	12.75
Louisiana.....	.98	11.12	9.94	11.05	11.41	11.83	11.90	12.87
Arkansas.....	.95	11.63	11.93	11.82	12.05	12.06	11.87	12.57
Mississippi.....	.98	12.03	13.13	12.94	12.93	13.01	13.13	13.31
Alabama.....	.96	13.23	12.90	12.95	12.97	12.91	13.06	13.00
Average price for belt.....	.....	12.73	12.28	12.28	12.76	12.58	12.12	12.76
Total number of samples of each staple.....	.....	457	556	6,840	7,510	10,084	2,275	1,191

¹ These averages relate to white cotton only. However, the average length of staple for the colored cotton was practically the same.

Table 3 shows that length of staple often does not receive proper consideration in pricing the farmer's cotton. A careful study of Table 3 will show that the average price paid for cotton of $\frac{3}{8}$ -inch staple was as high as that secured by the producer of 1-inch cotton, while the latter is worth probably \$5 more per bale for spinning purposes. In this connection it might be well to quote from a recent issue of the Farmers' Market Bulletin, published by the North Carolina Agricultural Experiment Station in cooperation with the State Department of Agriculture and the College of Agriculture, April, 1916, edition.

The difference in mill value between different staples varies according to the demand and supply. In a section in which the producers know what staple they have, they are reported to receive 25 points more for $\frac{5}{16}$ -inch staple than $\frac{7}{8}$ -inch staple, which is the basis; 50 points more for 1-inch, 100 points more for $1\frac{1}{16}$, 250 points more for $1\frac{1}{8}$, and 400 points more for $1\frac{3}{8}$ -inch staple. According to these figures, a farmer in such a section of the country would receive \$2.50 more for a 500-pound bale if it were 1-inch than he would if it had been $\frac{7}{8}$ -inch.

The injustice of the situation is emphasized when it is shown that $\frac{3}{8}$ -inch staple frequently brings the same price as staple of $1\frac{1}{16}$ inch, and occasionally the same as staple of $1\frac{1}{8}$ inch, when, according to the statement quoted above, $1\frac{1}{8}$ inch is worth \$17.50 more than $\frac{3}{8}$ -inch staple. It might be suggested that the difference in favor of the $\frac{3}{8}$ -inch cotton was caused by the fact that shorter staples usually

mature early, and that this early maturing may have resulted in a higher grade. However, during the first few months of the cotton season of 1913-14 the precipitation was unusually heavy, in some instances amounting to twice the normal. Presumably this was the reason that the cotton of $\frac{3}{4}$ -inch staple was lowest in grade, running 32 points off Middling, while all of the staples from $\frac{1}{8}$ to $\frac{1}{2}$ of an inch and longer ran a few points on Middling in value. These figures indicate that a large portion of the cotton crop is sold on averages, neither grade nor staple receiving proper consideration in many short-staple sections.

It generally is admitted that the majority of the buyers operating in sections which produce short-staple cotton have only a very limited knowledge of the various lengths of staple, as they have had practically no technical experience in stapling or "pulling" cotton. This is probably the principal reason why the present price conditions exist, but whatever the underlying cause, it can not be denied that under such a system of marketing the producer of better staple is not receiving a fair and just return for his product. It is manifestly unfair to the farmer who is producing a superior staple to have his cotton purchased at a price figured on the average cotton of a community, for naturally the average is low enough to protect the buyer from any possible loss. Under this system of marketing, it is often profitable for the producer to confine his efforts to the growing of the shorter lengths, for as a rule there is a correlation between length of staple and percentage of lint—usually the shorter the length of staple the higher the percentage of lint; therefore, at the same price per pound, the producer of the shorter staple would receive greater returns. Subsequent to this investigation campaigns have been conducted in many parts of the Cotton Belt with a view to teaching the producer the value of growing better staple and the need of greater care in handling his product, and the Office of Markets and Rural Organization has had frequent indications that those who are growing better staple are demanding and are often receiving the premiums to which their staple entitles them.

MARKETING TINGED AND STAINED COTTON.

The rainfall during the months of September and October, 1913, in the Cotton Belt was unusually heavy, in some sections amounting to twice the normal. This unusual precipitation, at a time when the cotton had matured, resulted in a large quantity of tinged and stained cotton; about 25 per cent of the 38,000 samples collected could not be classed on the permissive white grades. A study of the prices received for colored cotton shows ranges out of proportion to the values involved. While it is probably true that the buyer purchases a great deal of this cotton at a time when it is difficult to find a market

for it and his profits should be proportionately larger, still the range in prices indicates that little regard was shown to price differences as they existed in the spot markets, and that many farmers disposed of their product at prices far below its value. Tinged and stained cotton usually has been sold on type rather than on description, which fact has worked to the disadvantage of the producer who had this kind of lint, for it meant that the buyer had to purchase this cotton, send a sample to his brokers, and then receive an offer based on the type submitted. It is apparent that in naming a price to the producer, the buyer would make it so low that little if any risk would be involved.

In Longview, Tex., on November 22, two bales of the same grade of cotton were sold—one bale of 1-inch staple bringing $9\frac{1}{2}$ cents, and the other bale of $1\frac{1}{8}$ -inch staple, bringing $4\frac{1}{2}$ cents, a difference of 5 cents per pound, or \$25 per bale. It is probable that the producer owning the first bale knew something of values, and that the one selling for the lower figure knew nothing of grade or staple. In Boswell, Okla., on November 11, two bales sold at a difference of 431 points, or \$21.55 per bale. While these are the extreme variations between bales of the same grade in the same market, many instances of variations of over \$10 per bale are shown. As between different markets in the belt even wider ranges could be shown. While the two cases cited occurred in the West, where the widest ranges were usually found, still a condition almost as bad was revealed in the East. In Chapin, S. C., two bales of the same grade sold on the same day with a difference of \$13.50 per bale; El Dorado, Ark., \$13.75; and Albertville, Ala., \$10. As this survey shows that fully one-fourth of this crop was off-colored, some idea can be formed as to the losses which the producers probably sustained.

The fact that official standards for tinged and stained cotton have been promulgated¹ should enable the merchant to handle colored cotton in the future with little more risk than with white cotton. The decreased risk naturally will give greater stability to the market and should enable the farmer to secure prices which are more in line with the value of the product offered. Table 4 shows the wide range in prices paid in primary markets for tinged and stained cotton. It is but natural to expect a considerable range in prices, but there is no argument to justify a variation of 500 points in the same market on the same day for the same grade, especially when this difference amounts to more than was paid the producer for the lowest-priced bale.

It must not be supposed that the local buyer reaps the entire benefit of this loss, because he, too, is frequently not aware of the intrinsic worth of the cotton that he purchases. Probably this amount is absorbed gradually along the line, but the producer is the one who sustains the loss.

¹ Promulgated Jan. 23, 1916. See U. S. Dept. of Agriculture, Office of Markets and Rural Organization, Service and Regulatory Announcement No. 9, 1916.

TABLE 4.—*Variation in prices paid for tinged and stained cotton.*

Market.	Date.	Grade.	Length of staple.	Price.		Differ- ence in points.	Differ- ence per bale.
				High- est.	Low- est.		
South Carolina.							
Chapin.....	Dec. 15, 1913	S. M. stained ¹	<i>Inches.</i> 1	<i>Cents.</i> 11.50	<i>Cents.</i> 10.00	150	\$7.50
Do.....	Dec. 22, 1913	S. M. tinged.....	$\frac{1}{8}$	12.00	10.25	175	8.75
Seneca.....	Dec. 25, 1913	M. spotted.....	1	11.62	10.50	112	5.60
Do.....	Feb. 25, 1914	M. tinged.....	$\frac{7}{8}$	11.75	11.00	75	3.75
St. Matthews.....	Sept. 24, 1913	M. spotted.....	$\frac{3}{4}$	12.06	10.00	206	10.30
Do.....	Sept. 29, 1913	M. tinged.....	$\frac{3}{4}$	13.87	13.10	77	3.85
Do.....	Jan. 10, 1914	S. M. tinged.....	$\frac{1}{8}$	12.08	10.02	206	10.30
Chapin.....	Dec. 20, 1913	do.....	$\frac{1}{8}$	13.00	10.30	270	13.50
Louisiana.							
Monroe.....	Dec. 11, 1913	L. M. spotted.....	1	12.00	10.00	200	10.00
Arkansas.							
Searcy.....	Oct. 9, 1913	S. L. M. spotted.....	1	13.12	11.00	212	10.60
El Dorado.....	Nov. 6, 1913	L. M. stained.....	$\frac{7}{8}$	12.75	10.00	275	13.75
Camden.....	Nov. 20, 1913	S. L. M. spotted.....	$\frac{7}{8}$	12.25	11.00	125	6.25
Fordyce.....	Oct. 6, 1913	M. tinged.....	$\frac{1}{8}$	13.00	11.30	170	8.50
Alabama.							
Talladega.....	Jan. 23, 1914	S. M. tinged.....	$\frac{1}{8}$	12.75	12.25	50	2.50
Albertville.....	Jan. 22, 1914	S. L. M. tinged.....	1	12.00	10.00	200	10.00
Do.....	do.....	S. L. M. spotted.....	$\frac{1}{8}$	12.50	11.00	150	7.50
Eufaula.....	Nov. 20, 1913	L. M. blue.....	1	12.88	12.00	88	4.40
Huntsville.....	Dec. 11, 1913	M. tinged.....	$\frac{1}{8}$	12.00	10.50	150	7.50
Oklahoma.							
Atoka.....	Oct. 22, 1913	S. M. off.....	$\frac{1}{8}$	13.00	10.00	300	15.00
Boswell.....	Oct. 16, 1913	S. L. M. tinged.....	$\frac{1}{8}$	12.50	10.35	215	10.75
Do.....	Nov. 13, 1913	L. M. off.....	1	13.38	9.07	431	21.55
Chattanooga.....	Nov. 14, 1913	L. M. stained.....	1	9.50	8.00	150	7.50
Erick.....	Nov. 17, 1913	M. tinged.....	1	11.75	10.25	150	7.50
Georgia.							
Hartwell.....	Jan. 13, 1914	M. stained.....	$\frac{1}{8}$, $\frac{1}{16}$	12.50	10.50	300	10.00
Sandersville.....	Jan. 19, 1914	S. L. M. blue.....	1	9.00	11.00	200	10.00
Hoschton.....	Dec. 18, 1913	S. M. tinged.....	1	12.25	10.50	175	8.75
Washington.....	Nov. 28, 1913	do.....	1	12.56	10.50	203	10.30
Americus.....	Dec. 17, 1913	M. blue.....	$\frac{3}{8}$, $\frac{1}{2}$, $\frac{3}{4}$	11.50	9.50	200	10.00
Dublin.....	Dec. 5, 1913	M. spotted.....	$\frac{1}{8}$, $\frac{1}{16}$	13.00	11.75	125	6.25
Do.....	Jan. 30, 1914	M. blue.....	$\frac{1}{8}$, $\frac{1}{16}$	12.75	9.25	350	17.50
Sandersville.....	Jan. 10, 1914	S. M. off.....	$\frac{3}{8}$, $\frac{1}{2}$, $\frac{3}{4}$	12.00	9.75	225	11.25
Texas.							
Longview.....	Oct. 9, 1913	L. M. blue.....	1	10.60	7.60	300	15.00
Do.....	Oct. 23, 1913	L. M. off.....	1	11.50	8.50	350	17.50
Do.....	Nov. 22, 1913	S. G. O. stained.....	$\frac{1}{8}$, $\frac{1}{16}$	9.50	4.50	500	25.00
Sweetwater.....	Jan. 15, 1914	L. M. stained.....	$\frac{3}{8}$, $\frac{1}{2}$	10.00	6.30	370	18.50
Arkansas.							
Batesville.....	Nov. 20, 1913	M. tinged.....	$\frac{7}{8}$, 1	12.70	11.75	95	4.75
Camden.....	Nov. 20, 1913	S. L. M. spotted.....	$\frac{3}{8}$, 1	12.25	11.25	100	5.00
El Dorado.....	Oct. 9, 1913	S. L. M. off.....	$\frac{3}{8}$, $\frac{1}{2}$	12.75	11.25	150	7.50
Do.....	Nov. 7, 1913	L. M. blue.....	$\frac{3}{8}$, $\frac{1}{2}$	12.50	10.00	250	12.50
Fordyce.....	do.....	M. off.....	1	13.00	12.00	100	5.00
Hope.....	Oct. 23, 1913	M. spotted.....	$\frac{1}{2}$, $\frac{3}{4}$	14.00	12.25	175	8.75
Ola.....	Nov. 20, 1913	M. off.....	$\frac{3}{8}$, $\frac{1}{2}$	11.50	10.50	100	5.00

¹ In this table initials of grade names have been used.

SUGGESTED ECONOMIES IN HANDLING AND MARKETING COTTON.

This survey, together with the Oklahoma survey of 1912-13, has developed very clearly the fact that the present system of handling and marketing cotton can be improved materially. There is in the aggregate a tremendous economic waste all along the line from the producer through to the spinner.

The farmer should be convinced of the importance of producing good staple and of care in picking and housing it. The ginner should be required to operate his gins at the right speed—approximately 400 revolutions per minute for the average run of cotton—since fully 10 per cent of the samples in this investigation were so badly ginned as to be lowered about one grade in value. Assuming that the results of this survey fairly represent the condition in the Cotton Belt, the losses for the season of 1913-14 from poor ginning alone exceeded \$2,000,000.

Adequate covering for the bale is necessary to protect the lint, but excessive tare is uneconomical. H. W. Macalister, a leading member of the International Federation of Master Cotton Spinners' and Manufacturers' Association,¹ has stated that a change from the present system of selling cotton to selling on net weight would result in a saving to the producer on export cotton alone, based on 7,000,000 bales, of \$12,852,000, or approximately \$1.85 per bale.

Proper storage after ginning would result in a tremendous saving, as country damage assumes huge proportions. Warehouses are an economic necessity in a proper system of cotton marketing. In the years of abundant harvest the producer can store his cotton and with the warehouse receipt negotiate such loans as his needs may demand. Without the warehouse he has to market his cotton as rapidly as ginned, which results in a depression in prices incident to a glutted market, or he must subject it to country damage and other risks.

Figures obtained in the course of this study indicate that practically no premium is paid for the grades above Middling. Of the 38,000 samples collected, 9,916 bales were better than Middling, averaging 41 points above Middling in value, or \$2.05 per bale. Assuming that the crop of 1913-14 graded the same as the samples in this survey, it would indicate that the producers lost that year, through a failure to secure premiums on their high grades, a sum in excess of \$7,500,000.

When conditions are favorable, great economies may be effected through the organization of cooperative associations for the proper handling and marketing of cotton. Organizing on a community basis will permit the development and maintenance of a pure variety of cotton of a given length of staple. This development of one variety must be accompanied by better methods of harvesting, ginning, and storing. When the cotton is ready for marketing, better prices can be secured by assembling it at a central point, having it properly classed, and offering it for sale in even-running lots of grade and staple.

¹ U. S. Department of State. Special Consular Reports on Cotton Tare. 1912. See page 24.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 458

Contribution from the Office of Markets and Rural
Organization,
CHARLES J. BRAND, Chief.



Washington, D. C.



March 31, 1917

**HANDLING AND MARKETING DURANGO COTTON
IN THE IMPERIAL VALLEY.**

By J. G. MARTIN, *Investigator in Cotton Marketing*, and G. C. WHITE, *Specialist
in Transportation*.

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INTRODUCTION.

In the fall of 1915, the Office of Markets and Rural Organization of the Department of Agriculture, through cooperation with the Imperial Valley Long-Staple Cotton Growers' Association, rendered investigational assistance to the growers of Durango long-staple cotton in the Imperial Valley of southern California in the handling, classing, and marketing of their product.¹ The investigations were begun about the first of October, the beginning of the cotton-picking season in that section, so that besides the actual investigations an excellent opportunity was afforded not only to examine the condition of the Durango cotton in the fields (see fig. 1), but to inspect the methods of picking, handling, and storing the seed cotton on the farms, to study the methods of hauling the cotton to the gins, its subsequent ginning and baling, and its handling and storage in the yards. The specific investigations made included the manner

¹ Martin, J. G. The Handling and Marketing of the Arizona-Egyptian Cotton of the Salt River Valley, U. S. Dept. Agr., Bul. 311, 1915.

NOTE.—This bulletin should be of interest to farmers of the Imperial Valley and others located in sections where staple cotton is grown, and to cotton buyers generally.

of marking, tagging, and sampling the bales, concentrating the cotton into small lots of a few bales each, and into minimum car-load lots for compression.

Investigations were also made to determine the feasibility of marketing the Durango cotton direct to spinning mills at prices equal to those obtained by growers of staple cotton in the Mississippi Delta and other sections, where cotton of like staple is grown in sufficient quantities to interest spinners of fine yarns. This work was inaugurated through the growers' association, which seems to be successfully accomplishing the purpose for which it was organized.



FIG. 1.—A well-grown field of Durango cotton.

NECESSITY FOR CLEAN PICKING.

The boll of the Durango cotton is of the five-lock formation, slightly smaller than the boll of Mebane's "Triumph" or the Rowden varieties of short-staple cotton grown in the Imperial Valley, though not of sufficient difference in size to make clean picking noticeably more difficult.

The Durango fiber is strong, and has already attracted the attention of the cotton trade and spinners of fine and mercerized yarns in the United States. This cotton is utilized in the manufacture of fine goods, and for this purpose it must be free of motes and leaf so that the yarn may be spun evenly and be of uniform strength. In order to insure quick sales of cotton at good prices it should be picked as clean of leaf and other extraneous matter as possible. The

cotton mills that make fancy and high-class goods are willing to pay a premium for clean and well-handled cotton of the extra-staple varieties, as less waste is produced in the carding and combing processes.

The mills that buy staple cotton prefer the highest grades and will not accept cotton of lower grades than Strict Middling until quite late in the season, when the higher grades become scarce and they are forced to use a small quantity of Middling, in spite of the fact that all the grades by that time have been lowered by the effects of frost, which kills the foliage of the cotton plants. The dried leaves break up and adhere to the cotton as it is picked. It is a well-known fact that after frost has killed the plants the picker finds it difficult to gather the cotton in a clean condition.

The lower grades of staple cotton are difficult to sell on a staple basis. They are usually bought by spinning mills, which make certain kinds of goods that ordinarily require staple cotton to give the cloth strength, but which need not be of the finest quality. When the goods are intended for a use for which a showy appearance is not necessary, they can be made from low-grade staple cotton, but it must be remembered that this class of goods necessarily sells at low prices, and, therefore, the price paid for the cotton from which this cloth is manufactured must be in proportion to the price at which the latter is sold. To show how rapidly staple cotton depreciates in value as the grades are lowered by the increasing quantity of leaf contained in the seed cotton, the following statement of prices is given.

In making the following sales in the Imperial Valley, Strict Good Middling cotton of $1\frac{3}{16}$ -inch staple was taken as the basis of value, since it represented the early and clean-picked cotton.

Grade.	Net price received by grower.
Strict Good Middling--	17.30 cents.
Good Middling-----	17.05 cents, or 25 points less than Strict Good Middling.
Strict Middling -----	16.50 cents, or 80 points less than Strict Good Middling.
Middling-----	15.75 cents, or 155 points less than Strict Good Middling.
Strict Low Middling---	14.00 cents, or 330 points less than Strict Good Middling.

This means a difference of 330 points between the highest and the lowest grade shown, or a loss to the grower of \$16.50 for a 500-pound bale of cotton of the grade of Strict Low Middling, because the cotton contained "picks" and leaf and had been poorly ginned. There was also increased difficulty in selling low-grade staple cotton. At times, in order to interest the mills in the purchase of the lower grades of staple cotton, it was necessary to offer it at much wider differences between grades.

At present there is available a plentiful supply of pickers, including white settlers, Indians, Mexicans, Hindus, and Japanese, Chinese,

and negro pickers. The kind of work done and the resulting quality of the cotton depend largely, if not wholly, on the attention given to the matter by the growers themselves. Pickers of the same race were observed to give very different results according to the instructions and supervision given.

CARE OF SEED COTTON.

The gins in the Imperial Valley are located at the towns of Calexico, Heber, El Centro, Seeley, Holtville, Brawley, Wiest, and Calipatria, and there is a roller gin at Dixieland. As a rule, the cotton gins have no available storage facilities for taking care of the seed cotton, nor has the grower, who is in the habit of loading his



FIG. 2.—Seed cotton left on ground awaiting transportation to the gin.

cotton on the wagon as it is picked in the field and hauling it directly to the gin, where it is left on the wagon until it can be ginned. In the meantime the cotton that is being picked is placed in piles on the ground in the field to await the return of the wagon. (See fig. 2.) This careless manner of handling the seed cotton causes it to gather up leaf and trash from the ground when the wagon is being loaded. If the ground is damp, from irrigation or other cause, and the pile of cotton is not removed for some time, the cotton on the bottom of the pile will heat and become damaged as a consequence.

The amount of rainfall in the Imperial Valley is so small that it is not absolutely necessary for the grower to have houses in which to

store his seed cotton; but if he does not have at least two wagons so that one or the other may be always in the field to be filled with cotton as the pickers gather it, he should have tarpaulins or building paper spread on the ground so that the cotton may be emptied on them as it is picked. This method will keep the cotton clean and also will protect it from the dampness of the ground.

One cotton plantation in the valley has had installed at its local railroad station an automatic loader, driven by a gasoline engine, for use in transferring the seed cotton from the wagons to the cars. Attached to this machine is a cleaning device, and when the cotton is conveyed by suction from the wagon to the freight cars it is drawn over a grating through which fall the leaf and other impurities. This process of cleaning the cotton before it is ginned has been found to be of considerable value, as it not only serves to blow out the dust, but also removes enough leaf to raise the cotton in grade. Besides this arrangement for increasing the grade of its cotton, the plantation is very careful in picking and handling it, and the increase in price which it secured for cotton during 1915 should satisfy any farmer as to the importance of giving the very best care to the handling of seed cotton.

GINNING DURANGO COTTON.

It has been difficult to impress upon the ginners in the Imperial Valley the importance of ginning the Durango long-staple cotton smoothly and free of neps. The importance of proper handling and ginning of cotton, especially in long-staple districts, can not be over-emphasized. A good staple produced from pure pedigreed seed, if ginned green or damp or with gin saws running too fast, may be damaged in value from \$5 to \$25 or more a bale. On the basis of recent investigations by the Department of Agriculture the following suggestions are offered:

All cotton should be thoroughly dry before it is ginned. It is not possible for the ginner to turn out from green or damp cotton a good, smooth sample free from gin cutting and nepping.

Gin manufacturers agree that a reasonable speed of the saw shaft does not materially affect the quality of ginning, provided the brushes remove the lint from the saw teeth. It has been shown, however, that a proper speed is from 325 to 375 revolutions per minute on a 12-inch saw and from 375 to 425 revolutions per minute on a 10-inch saw.

Brushes should always be kept in the best condition and should be set so that the bristles reach to the bottom of the saw teeth.

The speed of the brush should be from 1,500 to 1,600 revolutions per minute. Whenever possible a brush driven independently of the

saw shaft is recommended. By this arrangement any change in the speed of the saw shaft does not affect the speed of the brush.

Other things being equal, it is impossible to lay too much stress on the condition of the roll in the ginning of long-staple cotton. It is impossible for the saws to pass through a hard roll without cutting or nepping the fiber. What is known as a slack or soft roll should be used for ginning long-staple cotton. This roll should be run just hard enough to prevent breaking, and the feed should be adjusted so as to keep it as nearly as possible of the same consistency throughout its entire length.

The huller breast is recommended in preference to the single-rib type for ginning long-staple cotton. The chief reason for recommending this type is that a more uniform roll can be made, and each lock of seed cotton is more thoroughly loosened before it reaches the gin roll. The huller breast also takes out the large trash.

The gins of the valley are all practically new and can be made to do excellent work if the ginner understands his machinery and is willing to make the effort to turn out cotton that is considered "well handled."

After impressing upon the local ginner the importance of ginning Durango smoothly, it was found that several of them were willing to make the necessary adjustments on their machines with a view to turning out first-class work, which they realized would bring to them a volume of trade which would more than reimburse them for the extra care taken and the reduced output. The results obtained so far have been very satisfactory to the grower of Durango as well as the ginner, as both have profited through the results of good ginning.

NECESSITY FOR GOOD BALING AND ADEQUATE COVERING.

The cotton, as it passes from the saws of the gin through the condenser, should come out in smooth and even layers; and if it is conveyed to the press box by air blast, the ginner should see that the cotton is not roped by the suction of the air, which sometimes twists it into short lengths roughly resembling cotton rope. Roughly handled or poorly condensed cotton that has been subjected to further impairment by roping, or twisting, will not press into the bale evenly and will be detected when the cotton is sampled, which will reduce its value materially when it is marketed. The mills that make fine yarns will not buy such cotton except at a considerable discount from the price usually paid for well-handled cotton of the same grade, since the latter produces less waste and gives less trouble in manufacturing processes. For this reason, if the cotton is condensed smoothly and evenly and is carefully conveyed to the press box and packed

into the bale in even layers, the samples that are drawn from the bale will be even and attractive to buyers.

When the bale arrives at the mill and is opened, the cotton can be taken off the bale in layers and mixed with other cotton with the least amount of labor. When such cotton is run through the pickers, cards, and combers, it not only will be easier to spin than cotton that has been carelessly handled, but the loss in waste will be much less, and the grower will reap the benefits to be derived from a careful ginning, baling, and covering of his cotton.

Up to the present time the local ginnerers have not given enough attention to this matter, with the result that some of the bales of

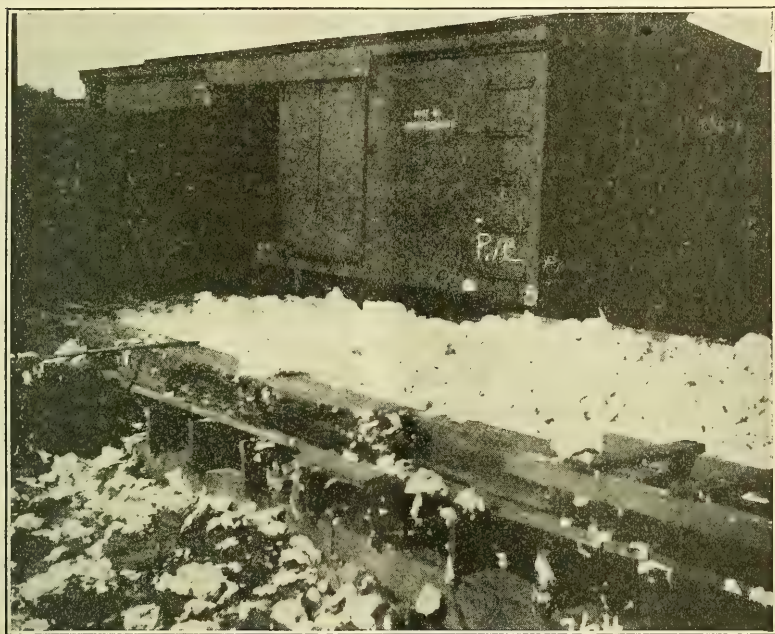


FIG. 3.—Pickings from one car of country-damaged cotton.

cotton on sampling have resembled repacked cotton. The growers and ginnerers of the valley can not afford to allow this loss to continue.

It is a well-known fact that the American square bale is put up in very poor material for handling and storing, and is the most insufficiently covered bale put on the world's cotton markets.¹ This complaint has been made not only by the spinning mills in the United States, but by those in Canada, England, and Europe. The loss in weight and damage to cotton that occurs while it is in transit

¹ Taylor, Fred, Griffith, D. C., and Atkinson, C. E. Ginning Information for Farmers. U. S. Dept. Agr., Farmers' Bul. 764, 1916.

is charged indirectly to the farmer. This would be understood readily by the grower if he were aware of the enormous amount of loose cotton which has to be picked from the bale while in transit because of the present quality of covering used.

The covering of the cotton of the Imperial Valley has been no exception to this unfortunate general rule. Sugar bags, reworked bagging, and bagging of too light quality have been used as coverings with much resulting waste. A good quality of new bagging or a heavy burlap of sufficient strength to withstand rough handling should be used in every case.

It has been estimated that the "city crop" of cotton for the entire South during 1915 amounted to approximately 100,000 bales. This total includes the samples that are necessary in selling cotton, but the greater part of the amount is composed of damaged cotton caused by inadequate covering and careless handling in transit. (See fig. 3.)

TAGGING, MARKING, BRANDING, AND WEIGHING.

As the Durango cotton varies so much in value according to the length of staple, character of the fiber, and the care with which it is picked and handled (which can give it a market value of almost, if not quite, double the value of short-staple cotton), it is essential that the bale should be identified properly. A good method consists of attaching to the bale a strong paper tag bearing a number, and also by marking legibly in ink on the bagging covering the bale. These marks will serve to identify the cotton in the course of shipment from point of origin to destination, and thus will prevent the good cotton from being mixed inadvertently with cotton of less value. The laborers who handle a bale of cotton from the time it is baled at the gin to the time it reaches its destination at the spinning mill are ignorant of its superior value. For these reasons it is urgent that the ginner tag the bale carefully and mark the grower's initials in ink on the head of the bale,¹ which will insure its identification at the compress. These marks also serve as a record for the association that handles the cotton or for the purchaser of the cotton.

When the cotton is delivered at the compress, a substantial tag with two perforated coupons attached is fastened to each bale. The tag and each coupon bear the same number. The bales are then listed and stored. If the grower should ask for the gin records he will be shown the list giving the corresponding gin-tag numbers and weight of the bales.

¹ Placing the grower's mark on the head of the bale is preferable to placing it on the side, as when the cotton is compressed the bagging on the end of the bale is first tucked in, preventing the initials, or marks, from being obliterated and serving to record the ownership of the bale, should there be any question as to its identity when it is opened at the mill.

The cotton is classed by means of tagged samples, and the samples are assembled in uniform lots. A list is then sent to the compress with instructions that certain bales be remarked with code words, such as "THAT," "SAFE," "PAST," etc.,¹ for identification, and that these bales be assembled, compressed, and, possibly, loaded for shipment. It is important that these new marks be large enough to be read easily and that a good quality of ink be used for this purpose, as the transportation companies follow these marks exclusively and treat each such lot of cotton, which may be composed of many bales, as an individual shipment. It is a common practice among shippers, in addition to the identification marks usually affixed, to brand their cotton to distinguish it as belonging to a special shipper.

In the early days of the cotton industry in the Imperial Valley there were no compresses, all the cotton being shipped out by gin weight only. In later years compresses have been installed, and as it is customary in the cotton trade to accept the weights as given by them, inasmuch as there is usually a certified, or public, weigher to oversee this matter, thus insuring accurate results, cotton producers in the Imperial Valley likewise have come to accept compress weights as correct.

STORAGE FACILITIES.

The facilities for the storage of cotton in the Imperial Valley are very poor and limited. This is probably due to the fact that the cotton industry in that locality is in its youth, and also to the small percentage of rainfall, which averages about $2\frac{1}{2}$ inches annually. Many of the growers in the valley assume that cotton can be laid on the ground and left there without deterioration until the prospective purchaser is ready to move it to the compress for compression and shipment. (See fig. 4.) This assumption is not justified, for during the past year cotton which has been exposed has been damaged as much in this section because of negligence on the part of the grower as it is damaged in the South where the rainfall is heavy and cotton is left unprotected on the ground.

According to present practice in the Imperial Valley, after the cotton is baled at the gin it is thrown out on the gin yard without the precaution of placing dunnage underneath in order to allow free circulation of the air on the lower side of the bales. When it is removed to the yard of the local warehouse the bales receive no better care, but are placed on end on the bare ground, where they remain unprotected until they are sent to the compress. Fortunately the cotton does not

¹ For convenience and regularity, words of four letters each are generally used.

remain very long either in the gin yard or in the warehouse yard, but during the unusual weather conditions that prevailed during the marketing season of 1914-15, when the demand for cotton was poor and prices were correspondingly low, and the grower was forced to carry over some of his crop until the fall of 1915, much of the cotton was "docked" or penalized from 5 to 20 pounds per bale on account of country damage; that is, much rotten or damaged cotton was picked off each bale before the bale was sold. This loss was attributable directly to the practice of storing the bales on the bare ground at the gin and in the warehouse yard. Country damage occurs on the farms, in the gin yards, warehouse yards, and the compress yards or wherever the bales are left standing or lying on damp or wet ground. There

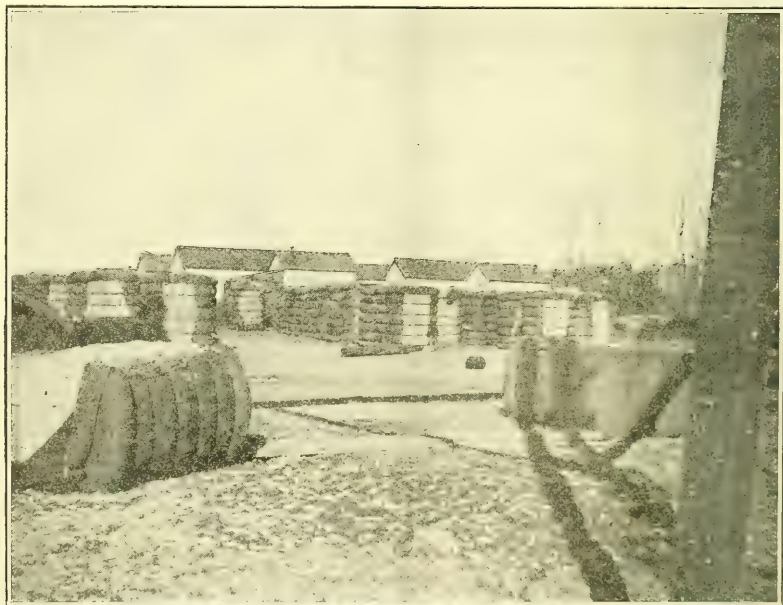


FIG. 4.—Cotton lying on the ground, subject to country damage.

was an unusual amount of rainfall during the season mentioned, but if the bales had been placed on dunnage there would have been no damage to the cotton. (See fig. 5.) Even though the ground may appear to be dry, there is always enough dampness from it to injure the fibers.

There is a clause in the marine insurance policies that covers country damage, and this cost for insuring the shipper's cotton against loss by country damage is charged back directly to the grower, inasmuch as the shipper calculates the cost of insurance and deducts it from the price to be paid to the cotton grower.

Sheds are not absolutely necessary in the Imperial Valley, as the rainfall is not sufficient to do any great amount of damage pro-

vided the bales are on dunnage and are rolled over after a rain so they may dry out on all sides. Of course, sheds would prevent a certain amount of loss in weight by protecting the cotton from the sun. For its weight and size a bale of cotton is the most valuable farm product grown in the valley, and therefore is entitled to as much care as any of the other crops produced.

SAMPLING.

The method of sampling the Durango cotton is similar to that followed throughout the South where staple cotton is bought and sold; that is, the bagging on the bale is cut open on one side in a crescent shape about 18 inches long, usually between the second and third

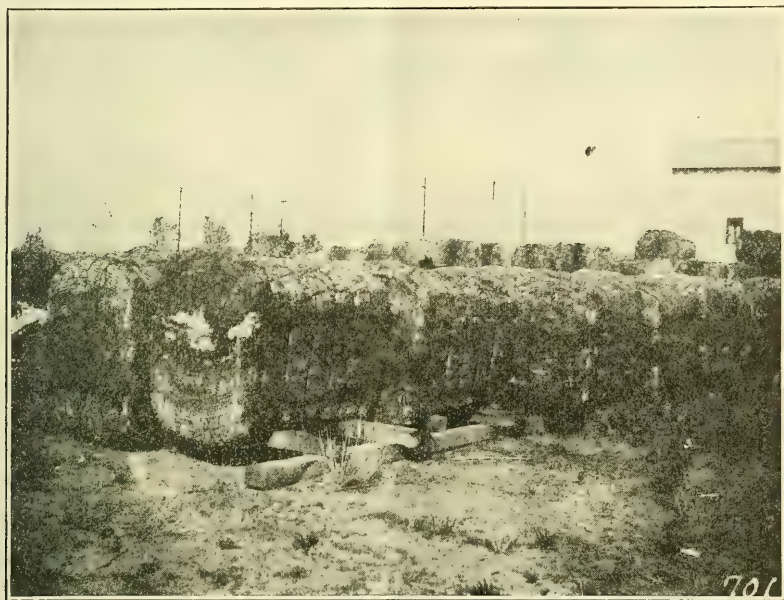


FIG. 5.—Cotton properly protected from country damage by dunnage.

band, and the flap thus made in the bagging is laid back. The first layer of cotton, which is generally dirty or discolored by the bagging, is pulled off and discarded. In order to obtain a representative sample it is necessary to secure the cotton from deeper in the bale and to draw it out in even and smooth layers. This procedure is repeated on the opposite side of the bale, after which one of the coupons is torn from the tag on the bale and placed between the two samples just drawn.

More skill in sampling is required than one not familiar with the cotton trade would suppose, and, therefore, it is important to both buyer and seller that the samples be pulled carefully and be representative of the bale from which they are taken. In drawing a

sample it is essential that the sampler should understand how to remove from the bale the cotton that may be discolored by the bagging or by dirt or mud, and at the same time he should take out any gin fall that may be in the sample, but he must be careful not to change the grade of the sample either by rough handling or by picking it to the extent that it will not represent the bale from which it was taken. When the cotton arrives at the mill or other destination and is resampled, if it is found to be not as represented, the purchaser will either reject it or make a claim for the difference in value between the original grade by which it was sold and that shown by the redrawn sample.

The present method of cutting the bale open and sampling the cotton each time a prospective purchaser wishes to examine it is an abuse that not only subjects the bale to loss in weight and otherwise damages it, but also increases the risk of fire. With the continuance of this custom it will be difficult to avoid the resampling of cotton, especially of staple cotton, in view of the fact that there is such a wide variation in the price of such cotton, according to the length of the staple and its grade. When a buyer contemplates paying a premium for a lot of staple cotton, it will be seen readily that his reasons for wishing to sample the cotton beforehand and pass judgment upon it personally are justified.

CLASSING DURANGO COTTON.

The Durango is a new variety of upland-staple cotton developed by the United States Department of Agriculture¹ and introduced into the Imperial Valley during the year 1910 as a long-staple cotton suited to the local climatic conditions. The lack of rainfall and the long and hot season in this valley make the section ideal for the growing of cotton of long staple and of a bright and bloomy color, both essential qualities in the manufacture of fine yarn. Of the varieties tried, it was found that the Durango cotton responded best to the conditions existing in the Imperial Valley; hence this variety for that locality is recommended and encouraged by the United States Department of Agriculture.

There are no established types or standards that may be used for classing the Durango cotton other than the Official Cotton Standards of the United States for grade and the standards for length used by shippers of upland-staple varieties throughout the southern staple districts, which are $1\frac{1}{16}$ inches, $1\frac{1}{8}$ inches, $1\frac{3}{16}$ inches, $1\frac{1}{4}$ inches, $1\frac{5}{16}$ inches, etc. The Durango cotton grown by irrigation in the Im-

¹ Cook, O. F., Durango Cotton in the Imperial Valley. In U. S. Dept. Agr. Bur. Plant Indus. Circular 111, pages 11-22, 1913.

McLachlan, Argyle. Community Production of Durango Cotton in the Imperial Valley. U. S. Dept. Agr. Bul. 324, 1915.

perial Valley is commonly of a brighter and more "bloomy" color than the staple cotton grown in the South; it contains less leaf in the early part of the picking season, but more fine or pulverized leaf during the latter part of the season than is found in cotton of similar grades grown in the Mississippi Delta.

The actual tagged samples representing the grades and staple of the lots of cotton classed were sent to cotton-mill brokers and direct to the spinning mills that manufacture fine yarns. Each list of 50 bales sent out, as shown by samples, represented cotton of a certain length of staple and grade. For example, lot No. 1 (50 bales), marked "WILL," represented Strict Middling and Good Middling, $1\frac{1}{8}$ -inch staple; lot No. 2, marked "MIKE," Good Middling and better, $1\frac{1}{8}$ -inch staple; lot No. 3, marked "TOMY," Strict Middling and Good Middling, $1\frac{3}{16}$ inch; lot No. 4, marked "TIME," Good Middling and better, $1\frac{3}{16}$ inch; lot No. 5, marked "EDGE," Strict Middling and Good Middling, $1\frac{1}{4}$ inch; and so on. In this way types were established which represented all combinations of grades and staples raised in the valley.

After types were established and recorded as a basis for trading between the association and the brokers and mills, it was a comparatively simple matter to class the cotton equal to the types. This method of classing was carried on throughout the season, and proved satisfactory. The spinner who possessed types knew exactly the staple, grade, and character of the cotton he was buying when he ordered cotton equal to a certain type.

When samples were sent to the association's sample room for classing, each bale was graded, stapled, and given a mark. These marks were entered in the type book as being equal to an established type of similar grade and staple.

During the early fall Durango cotton which was picked with care was of a superior grade, much of it being Strict Good Middling. Even to the time of the first heavy frost, November 12, 1915, which occurred from 15 to 20 days earlier than usual, the cotton was of a very good quality and grade when care was exercised in its picking and ginning. After this frost, which killed the cotton plant, the grades were much lower on account of the difficulty of picking the cotton free of leaf. Cotton which was still in the boll was lowered in grade by the effects of the frost, which caused discoloration from light tinged spots to a deep yellow tinge throughout the cotton.

LENGTH AND CHARACTER OF DURANGO STAPLE.

The Durango cotton varies in length of staple from $1\frac{1}{16}$ inch to $1\frac{5}{16}$ inch. Its character is very good; the fiber is silky and has considerable spirality, it is exceptionally strong and even in length, and free

from waste, when grown in rich soil which is sufficiently irrigated and when the cotton has been carefully picked. The $1\frac{1}{16}$ -inch staple Durango cotton and the greater portion of the soft and wasty-fiber cotton grown in the Imperial Valley during the season 1915-16, was found to be volunteer or "ratooned" Durango.¹

The Durango cotton of $1\frac{1}{8}$ -inch staple may be produced by several different causes. Durango seed from $1\frac{1}{8}$ -inch staple will reproduce cotton of similar staple, provided it is planted in soil of equal richness, given the proper cultivation, and is sufficiently irrigated. The same rule holds good in the production of $1\frac{2}{16}$ -inch, $1\frac{1}{4}$ -inch, and $1\frac{5}{16}$ -inch staple cotton from Durango seed. Cotton picked from bolls killed by frost will be found to be of weaker staple than that gathered from mature bolls.

The various lengths of staple of Durango cotton may be attributed to the quality of the seed planted and the condition of the soil, such as soft, hard, or sandy loam, which determines the readiness of the soil to absorb water when irrigated and its capacity to retain moisture. It is very important that the land should be level, so it can be irrigated evenly, the water being distributed equally over the field. If the soil is of equal quality over such a field, the length of the staple of cotton grown therein will be uniform. When the length of staple varies in the same seed in the same or in adjacent fields, it is usually because of a difference in the quality of the soil or because the land is not level, which prevents uniform irrigation.

Studies indicate that the length of staple will deteriorate if the seed is planted in soil that is depleted of nitrogen and humus matter, or in soil which contains too much alkali. It is said that the staple will also deteriorate if the land has not been put into good condition beforehand, or if it is not well cultivated afterwards and given the proper amount of water.

The Durango staple will increase in length, strength, and silkiness, provided the seed is planted in good, rich soil. A light loam that has been planted in alfalfa for several years and pastured and then put into good condition, cultivated well, and irrigated throughout the growing season should produce an excellent staple. There are records of Durango cotton grown in such land which stapled $1\frac{5}{16}$ inches in length and which sold at top prices in eastern markets.

MARKETING OF DURANGO COTTON.

During the season 1915-16 Durango cotton of the Imperial Valley was marketed in various ways, the growers' association utilizing existing methods and also devising others of its own.

¹ Scofield, C. S., Kearney, T. H., Brand, C. J., Cook, O. F., and Swingle, W. T., Community Production of Egyptian Cotton in the United States. U. S. Dept. Agr. Bul. 332, 1916; see page 25.

LOCAL BUYING IN THE IMPERIAL VALLEY.

There are several local buyers and several exporting firms, represented by local buyers, in the Imperial Valley. Their business is conducted in this locality on the same basis as it is in the small towns of the Southern States. The local buyer establishes his headquarters in one of the larger towns convenient to the cotton section in which he is operating. Either he has a local buyer stationed in each of the smaller neighboring towns where cotton is ginned or he keeps in direct touch with the ginner or warehouseman, usually by telephone. When he learns that there is cotton for sale at a certain town he immediately sends his buyer to examine and class this cotton and to offer the grower a price for it.

In the Imperial Valley the town of El Centro is centrally located for the cotton business, and the majority of the buyers have their headquarters there. The town of Calexico, which is near the Mexican border, has a compress and a number of modern gins, and draws cotton from both the American and the Mexican side of the border. The receipts at Calexico are larger than at any other point in the valley, and the buyers in El Centro will visit Calexico whenever cotton is offered for sale at that point. When a grower wishes to sell to local buyers, he informs the manager of the compress of the fact. Employees at the compress take samples and lay them out on tables. The buyers who are interested are invited to examine these samples and to submit sealed bids to the manager. After all the bids are in they are opened by the manager and the bids are compared, the highest bidder being awarded the cotton at the price he has offered. The compress then weighs the cotton, if it has not been weighed previously, and the buyer gives his check to the grower in return for the compress receipts covering the cotton in question, and the transaction is closed. This method of selling is satisfactory to the grower, as he knows how much he will receive for his cotton, the sale is made within a day, and he usually receives his money promptly.

In making sales of cotton in the smaller towns, such as Imperial (where there is a compress), El Centro, Seeley, Holtville, and Brawley, the buyer interviews the grower who has a bale or a number of bales to sell; he examines the cotton and makes the grower an offer for it. If there should be more than one buyer present, the farmer sells his cotton to the buyer offering him the best price, while if there is but one buyer the grower, if forced to sell the same day, has to accept whatever price the buyer offers. The price paid by the local buyer is based upon the quotations for similar cotton in the ports of New Orleans and Galveston, less the

broker's commission, freight to the ports, compressing, and other compress charges, and all other local charges to which the cotton is subject, plus the commission or profit to the original buyer. It is understood, of course, that the buyer purchases the cotton at such a price as will insure a profit on the transaction in the event of any change in the market before he in turn can sell to the broker or direct to the mill, as the circumstances warrant.

The Imperial Valley Long-Staple Cotton Growers' Association sold some of its cotton through these buyers, who also handled all of the cotton produced by growers in the valley who did not belong to the growers' association.

DIRECT MARKETING BY THE GROWERS' ASSOCIATION.

In marketing its Durango cotton independently, the growers' association had samples drawn from both sides of each bale of cotton, as previously described, and coupons from the tags on the bales were placed in the samples. The samples were then sent to the office of the growers' association, where they were laid out on the tables to be graded and stapled. Cotton of similar grade and even lengths of staple was classed into lots of 50 bales each. A designating mark of four letters was placed on the wrapper covering the samples and the tag list was entered in the type book, with all information concerning the cotton, including grade, staple, ownership, and the type to which the lot was equal.

The samples were then sent to the prospective purchasers known by the association to be in the market for such cotton. On the arrival of the samples at the cotton mills, their classer examined them and if, in his judgment, the cotton represented by the samples submitted was suitable for their requirements they asked for a firm offer. Upon receipt of the offer, if the price was considered reasonable by the mill treasurer, he accepted it or made a counter offer of a price which he considered as the market value of the cotton, or its value to his mill. These transactions were all carried on by telegraph, for, according to the custom of the trade, firm offers hold good only for the day, unless otherwise stated. For instance, the owner, whether he is the buyer, broker, or representative of the association, will usually offer cotton under the following terms: "We offer firm, NELL 50 bales. MIKE 50 bales, at 20 cents f. o. b., and freight to mill." Limitation may be placed on an offer in many ways.

The marketing of staple cotton at full price is a difficult matter. It rests first on the ability of the classer to make up lots of 50 bales each of similar grade and equal length of staple. Then it is necessary to offer the cotton so as to secure the full market price, yet at the same time the final purchaser, the mill treasurer, must feel that

he is receiving full value for his money. To manage such sales to the satisfaction of all concerned requires a certain amount of skill and ability.

The demand for cotton is based on the activity of the yarn or goods market, which in turn hinges upon the style of goods being worn or utilized, and upon the general financial conditions. When the supply of cotton is unusually large, low prices with dull and inactive markets for staples must result. In times of prosperity naturally more money is spent on dress goods and other articles of fine quality than in seasons of financial depression, and there is a good demand for material at high prices. This demand means an active staple-cotton market and high prices, but, of course, the law of supply and demand applies to cotton as well as to any other commodity.

As previously stated, the high grades of cotton are those in greatest demand; in fact, a mill spinning fine yarns for the weaving of fancy and high-grade goods will not buy low-grade staple cotton. Staple cotton of the Durango variety ranges in length from $1\frac{1}{16}$ to $1\frac{5}{16}$ inches, and for each increase of one-sixteenth of an inch in length of staple in the grade of Strict Middling and Good Middling, and better, there is an increase in price of about 1 cent a pound. These differences in value between the various grades are not stable, but vary with the demand for the different lengths of staple, and also change with the grade and quality or character of the cotton. For instance, Good Middling, $1\frac{1}{4}$ inch, grown on poor land which has been insufficiently irrigated, will make irregular, soft, and fluffy fiber which will not equal in value cotton of the same grade and length of staple grown under proper conditions. As poor or faulty ginning also will reduce the value of the staple materially, in the marketing of long-staple cotton it is necessary to take into consideration every good quality and all defects, whether inherent or produced mechanically.

TRANSPORTATION FACILITIES AND RATES.

Although this bulletin discusses handling and marketing primarily with reference to the Durango cotton produced in the Imperial Valley, what is said concerning transportation rates and facilities applies to all classes of cotton grown there. So far as is known, prior to the season of 1916-17, little of the Imperial Valley cotton was exported to the Orient from Pacific coast ports. A small portion of it is consumed by the mills of the Southeast; some of it moves through the ports of Galveston and New Orleans to Europe; and some of it moves to those ports and thence by water to New York for consumption at interior mills.

The local rates from New York to the interior mills are the same for all cotton moving from any section by that route to ultimate points of consumption. Similarly the ocean rates from the ports of Galveston and New Orleans both to New York and to European ports are the same for all cotton, whether produced in the Imperial Valley or elsewhere. In considering the higher rate to market which is paid on Imperial Valley cotton, it is necessary to take into account merely that portion of it which applies from Imperial Valley points to the ports of Galveston and New Orleans.

Prior to the beginning of the production of cotton in the Salt River Valley of Arizona and in the Imperial Valley of California, the railroads west of El Paso, Tex., and Albuquerque, N. Mex., had had no experience in the transportation of cotton except in carload lots from the cotton belt destined to Pacific coast mills and to Pacific coast ports for exportation to the Orient. On the cotton shipped for consumption at Pacific coast mills, a transcontinental domestic rate of 95 cents per 100 pounds had been established, which rate included 10 cents for compression in transit. The through export rate from the cotton belt to the Orient via Pacific coast ports was very little, if any, higher than the domestic rate to Pacific coast cities, and, in dividing it, the amount received by the rail carriers for the haul to the Pacific coast was much less, of course, than the domestic rate to the Pacific coast.

When it became necessary to establish an eastbound transcontinental commodity rate for the cotton of the Imperial Valley, the through export rates to the Orient had been canceled, and the rail carriers were receiving for the haul from the cotton belt to the Pacific coast the same amount on both domestic and export shipments. With a rate thus established for the westbound movement, it was taken as a standard, and the eastbound rate was made the same.

The eastbound rate of 95 cents, including 10 cents for compression, leaving a net transportation rate of 85 cents, remained in effect till the summer of 1915, when it was raised to \$1.05, including 15 cents for compression and leaving a net transportation rate of 90 cents. The advance of 5 cents in the net transportation charge was permitted by the Interstate Commerce Commission on the showing by the carrier of a higher cost of performing the eastbound service. The present proportional any-quantity rate on compressed cotton from both Galveston and New Orleans to New York is 25 cents per 100 pounds, which makes a through carload net rate from Imperial Valley points of \$1.15.

The cotton acreage in the Imperial Valley has increased rapidly under the stimulus of the unusual conditions which recently have affected the world's markets, and apparently the existing high prices of cotton are sufficient at the present time to counterbalance a freight

rate higher than that paid by the cotton belt. Attention may be called, however, to the possible entry into the situation in the not distant future of new factors which may result in a lower rate by other routes.

Granted vessel space, it would be possible to move the Imperial Valley cotton to eastern United States and European markets through the Panama Canal from the port of San Pedro. Calexico, the southernmost point in the Imperial Valley, is 248 miles from San Pedro, and the carload cotton rate from all points in Imperial Valley to San Pedro is 40 cents per 100 pounds. Before the European war an ocean rate of \$7 per ton was available through the canal from San Pedro to New York. If, after the close of the war, when a large tonnage of vessels will be released for peaceful commerce, the ocean rate is equally favorable, the freight charge by the canal route will be less than by rail, even with the additional expense of marine insurance and the cost of transfer at San Pedro from cars to vessel.

No figures are available to make a comparison of through rates to European ports via San Pedro with those via Galveston or New Orleans, but the rate via San Pedro under normal conditions would probably be the lower. The rail rate from the Imperial Valley to San Pedro is 65 cents less per hundred pounds than the rates to the Gulf ports, and it is not likely that the ocean rates from San Pedro to New York and to European ports would exceed the rates from the Gulf ports by so large an amount.

The freight rate alone is not always the determining factor in the selection of one route in preference to another. Consideration is given to questions of service, and an important element of service is the length of time in transit. The present average time by the rail-and-water route through Galveston or New Orleans is two weeks to either of those ports, plus an additional week to New York. Records of past sailings indicate that there would be an advantage in time in shipping to New York via San Pedro through the canal.

In connection with the water route through the canal, mention should be made of the railroad now under construction between San Diego and El Centro, the completion of which will give the valley an outlet for its cotton through an additional Pacific port. Although San Diego is 102 miles south of Los Angeles Harbor (San Pedro), and therefore somewhat nearer the Panama Canal, yet in view of the fact that the total distance from San Diego to New York is approximately 5,000 nautical miles, and that to Liverpool is in excess of 7,000 nautical miles, it is not likely that this slightly shorter distance from San Diego will make any difference in the ocean rate. With respect to the rail haul, however, the average distance from all cotton-ginning stations to San Diego will be 85 miles less than to San Pedro. If account be taken only of Imperial and Calexico, at which

stations about 80 per cent of all the cotton originates, the average distance will be 100 miles less. So great a decrease in the distance probably would have the effect of reducing the local rate to the Pacific port, with a consequent lessening of the through rate to New York and to European ports.

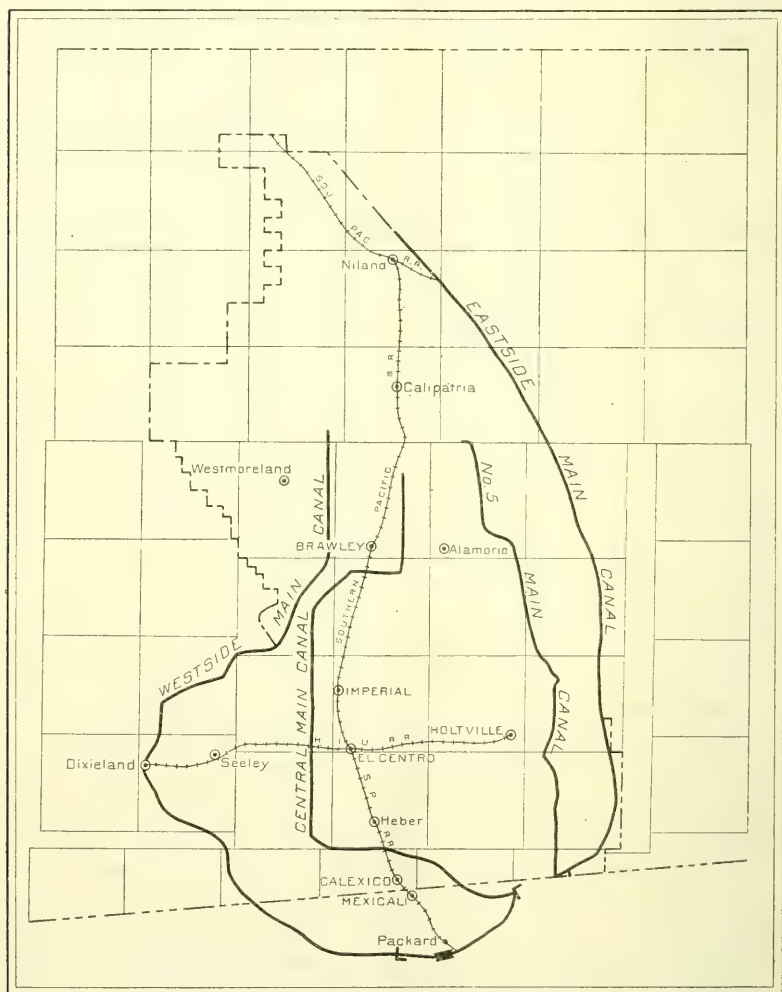


FIG. 6.—Map of the Imperial Valley.

The Imperial Valley is served by a 40-mile branch of the Southern Pacific Railroad, which extends south from Niland to Calexico on the Mexican boundary. (See fig. 6.) Connecting with the Southern Pacific at El Centro, the Holtan Interurban, an independent railroad, extends east to Holtville, a distance of 10.5 miles, and west to Dixieland, a distance of 13.7 miles. On the Southern Pacific Railroad are located seven gins and two compresses, the compresses being at Im-

perial and Calexico. The through rates to eastern mills and markets are so adjusted as to make it more economical to compress the cotton in the valley than to forward it in flat bales uncompressed, as beyond Niland there are no compresses available until shipments reach the vicinity of San Antonio, Tex., some 1,200 miles from the point of production.

The tariffs require the payment of local charges from the ginning point to the compress point on delivery of every shipment at a compress. When the cotton has been compressed and is ready to be re-shipped, the local charges which have been paid for the transportation to the compress point are refunded on such part of the outgoing cotton as moved to the compress point in carload lots. Five working days are allowed for the service of compression, but the local charges will not be refunded unless the cotton is reshipped within one year from the date of its arrival at the compress point. To this extent then the transportation arrangements are equivalent to the compression-in-transit privilege which prevails in the cotton belt.

No refund is made of the local transportation charges on cotton reaching the compress point in less-than-carload lots, and in this respect the situation is different from that of the cotton belt, where cotton moves on an any-quantity rate from the ginning point through the compress point, with privilege of compression in transit to market or to a seaport.

The tariffs further provide that the carrier will not assume the cost of unloading or reloading shipments at transit points; that is, at the compresses. This is in line with similar requirements of carriers in the cotton belt.

As there are three gins located north of Imperial, it is necessary to back haul some of the cotton in order to reach a compress. The situation thus differs very materially from the situation in the cotton belt, where the gins and compresses are more numerous and more widely distributed, and where the location of the compresses is such that a back haul is necessary only in very rare instances, if at all. Not only is there granted in the Imperial Valley the unusual privilege of a back haul in connection with the transit privilege of this kind, but, so far as concerns carload shipments, the back haul is made free of charge.

Little information is available as to the quantity of cotton shipped to compress points in less-than-carload lots, which incurs rail transportation expense in addition to the transcontinental rate for the eastbound movement. About one-third of the crop for the season of 1915-16 was marketed through the Imperial Valley Long Staple Cotton Growers' Association, and the records of the association show that less than 2 per cent of the cotton that it handled was

thus affected. The records do not show, however, from what stations these less-than-carload shipments were made, so that it is impossible to determine the aggregate additional rail transportation expense.

Gins are located on the Holton Interurban Railway. All cotton which is shipped from these gins to a compress must pay the local charges on this railroad to El Centro, no part of which is refunded. Beyond El Centro compression in transit is permitted, and the charges on carload shipments to compress points are refunded under Southern Pacific tariffs, as has been described above.

The excellent roads of the Imperial Valley, which are seldom disturbed by rainfall, make it more economical in some cases to haul cotton by autotrucks or wagons to compress points. In actual practice it would seem that a relatively small amount is hauled in this way. If the experience of the Imperial Valley Long Staple Cotton Growers' Association is representative of that of all the shippers in the valley, the amount so transported is slightly in excess of 3 per cent. In computing the total transportation expense, however, account must be taken of the cost of the haul by wagon and autotruck.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 459



Contribution from the Bureau of Animal Industry.
A. D. MELVIN, Chief.

Washington, D. C.



December 15, 1916

THE USE OF ENERGY VALUES IN THE COMPUTATION OF RATIONS FOR FARM ANIMALS.¹

By HENRY PRENTISS ARMSBY, *Director of the Institute of Animal Nutrition of The Pennsylvania State College; Expert in Animal Nutrition, Bureau of Animal Industry.*

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GENERAL PRINCIPLES.

COMPONENTS OF THE ANIMAL BODY.

THE MACHINERY OF THE BODY.

The essential working parts of the body contain a great variety of substances, but these may, for our present purpose, be grouped under three heads—water, ash, and protein. The bones, constituting the framework of the body; the ligaments, muscles, and tendons, which bind together and move the bones; the skin and hair, or wool, which cover and protect the body; the internal organs of circulation, respiration, digestion, excretion, and reproduction; the brain and nerves—in short, the whole mechanism of the body—can be regarded as being composed substantially of these three classes of substances.

Water.—Rarely less than half and sometimes as much as three-fourths of the weight of the live animal consists of water. The

¹ A revision of Farmers' Bulletin 346.

proportion of water is greatest in young and lean animals and decreases as they become more mature or fatter.

Ash.—The ash or mineral matter is the portion left after complete burning. Its presence is most familiar in the bones, but it is found in all parts of the body and is just as essential as water or protein. It amounts to from 2 to 5 per cent of the weight of the body.

Protein.—Protein is the name given to a highly important group of substances, of which the white of egg, washed lean meat, the casein of milk, the gluten of wheat flour, etc., are familiar examples. They are composed of the chemical elements carbon, hydrogen, oxygen, nitrogen, and sulphur. They are what are commonly called "organic" substances, which simply means that they may be burned completely in air or oxygen. They differ from the other groups of substances found in the animal body in containing sulphur, and especially nitrogen, the latter element constituting from 15 to 18 or 19 per cent of their weight.

Protein is the basis of the living tissues of the body—the so-called protoplasm—and is the substance through which life especially manifests itself. In the body it is always associated with water and ash.

THE RESERVE MATERIAL OF THE BODY

Fat.—Besides its working parts, the body contains a store of reserve material in the form of fat. While the fat deposits in the body are of use mechanically as cushions between the various organs and as a protecting layer under the skin, nevertheless fat represents essentially a storage of material derived from feed consumed in excess of the body's immediate needs. When the feed is insufficient or entirely lacking, this store of surplus material is drawn upon, and the animal gradually becomes lean. The percentage of fat in the bodies of agricultural animals may vary greatly but seldom falls below 6 or rises above 30 per cent.

Glycogen.—Besides fat there are stored up in the muscles, liver, and other organs of a healthy animal rather small amounts of a substance called "glycogen," belonging to the group of carbohydrates described in the next section. Neither fat nor glycogen contains the elements nitrogen or sulphur, but each is composed entirely of carbon, hydrogen, and oxygen.

COMPOSITION OF THE ENTIRE BODY.

The average results of analyses shown in the following table indicate the composition of the bodies of different animals in different conditions:

Percentage composition of live animals.

	Ox.			Fat calf.	Sheep.					Swine.	
	Well fed.	Half fat.	Fat.		Lean.	Well fed.	Half fat.	Fat.	Very fat.	Well fed.	Fat.
	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
Water.....	54.3	50.2	43.6	60.1	56.6	53.7	50.7	44.8	39.0	53.9	42.0
Ash.....	4.8	4.4	3.9	4.5	3.4	3.3	3.2	2.9	2.8	2.7	1.8
Fat.....	7.1	14.9	26.8	13.1	8.6	13.2	18.3	28.1	37.2	22.5	40.2
Protein.....	15.8	15.5	13.7	15.3	15.4	14.8	13.8	12.2	11.0	13.9	11.0
Contents of stomach and intestines.....	18.0	15.0	12.0		16.0	15.0	14.0	12.0	10.0	7.0	5.0
Total.....	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

COMPONENTS OF FEEDING STUFFS.

Like the animal body, the vegetable feeding stuffs which nourish it contain a great variety of substances, but these, too, like those of the animal, may be classified into a few groups. Not only so, but these main groups are the same as those found in the animal, viz, water, ash, protein, fats, and carbohydrates. The proportions of these ingredients in the animal body and in vegetable substances, however, are widely different.

PROTEIN AND FAT.

Protein is the predominant ingredient, aside from water, in the animal body, while the latter stores up its reserve material in the form of fat, with but little carbohydrates (glycogen). Protein is also contained in all plants and, as in the animal, forms the basis of the living tissues, but the predominant ingredients as regards quantity are the carbohydrates. In the form of cellulose, or "crude fiber," they form the cell walls of the plant, while as starch and sugar they are stored up in large amounts in the cells of seeds and roots as reserve material. A few plants, like flax and cotton, store up oil instead of starch and are likewise rich in protein, but, as a rule, the common feeding stuffs contain relatively small amounts of protein and fat and are rich in carbohydrates.

The protein and fats of plants are not widely different from those of animals and call for no special description here.

CARBOHYDRATES.

The carbohydrates, as starch, sugar, etc., constitute a distinct group, represented in the animal chiefly by the small amounts of glycogen mentioned on page 2 and by the sugar of the milk. They are composed of the chemical elements carbon, hydrogen, and oxygen, the two latter being present in exactly the same relative amounts as

in water. Like the fats, they contain no nitrogen or sulphur, but they differ from the fats in containing less carbon and more oxygen.

The carbohydrates of feeding stuffs may be divided into two classes. The first of these includes those substances which are found in the cell walls and constitute the framework of the plant. This class includes cellulose and a great variety of other substances, most of which are rather difficult to dissolve. The "crude fiber" obtained in the analysis of feeding stuffs represents this class of carbohydrates.

The second class of carbohydrates consists of the reserve material stored up in the cells and includes starch, the various kinds of sugar, and other less familiar substances. Some of these carbohydrates, like the sugars, dissolve in water and all may be converted into soluble forms rather easily. In analyses of feeding stuffs they are contained in the "nitrogen-free extract" which, however, also includes a variety of other substances of ill-defined nature.

THE ANIMAL BODY AS A MACHINE.

Mechanically the body of an animal is a very wonderful machine, but what is of peculiar interest in this connection is that the body is what the engineer calls a prime motor—that is, like the steam or gasoline engine, it moves itself and may supply power to move other machines. In fact, there is in some respects a very close likeness between the animal body and what are known as internal-combustion motors, i. e., those engines in which power is developed by burning liquid or gaseous fuel (gasoline, alcohol, producer gas, etc.) in the cylinder of the engine itself. Such an engine requires two things for its operation: (1) Sufficient repair material to keep its working parts in running order, and (2) a supply of fuel in proportion to the work to be done. Just these same two things are what the animal requires—repair material and fuel.

In one respect, however, the animal body differs from the artificial machine—it can not be stopped and started again at will. As long as the animal lives the vital machinery is in operation, although less actively at some times than at others. The animal might be compared to an automobile whose engine must be kept running at a low speed in order to have the power available when needed. Consequently, the animal requires to be supplied with repair material and with fuel as long as it lives and not merely when it is in active use.

That the feed of the animal is its source of both repair material and fuel is sufficiently obvious. We do not need a physiologist to tell us that when an animal is deprived of feed its tissues waste away while its fat is burned up in the effort to keep the bodily machinery in motion. We may proceed at once, therefore, to consider the feed in these two relations.

THE DEMAND FOR REPAIR MATERIAL.

The repair material for any machine must be of the same kind of which the machine is made. We have just seen that the machinery of the body is composed of protein, ash, and water. These, then, are the materials which must be supplied to keep it in repair.

Water, of course, is or should be abundantly supplied in the drink and scarcely need be considered in a discussion of rations.

Ash.—The ash supply has received less attention in the past than its importance deserves. In the ordinary operation of the bodily machinery its ash ingredients are being continually excreted and the feed must supply ash sufficient in amount and of the right kinds to make good the loss, while the growing animal needs an additional supply for building up its new tissues. Fortunately, normally constituted rations appear rarely to be deficient in ash. Usually it is only when large amounts of certain by-product feeds are used or when there is a misrelation between grain and coarse fodder that special attention needs to be given to the ash supply.

Protein.—The protein supply, on the other hand, calls for careful consideration. Protein is the characteristic ingredient of the animal mechanism and is broken down and destroyed in its operation at a fairly regular rate. Moreover, since the bodily machinery is running all the time, whether any external work is done or not, this loss is continually going on.

The body differs from a machine in being self-repairing, but it can not manufacture protein for repair purposes out of the carbohydrates and fats of its feed any more than it is possible to make repairs for an automobile out of the gasoline which supplies the power. For its protein the body is absolutely dependent on the protein of the feed. This protein is needed for two purposes.

First. It is required for repair purposes in the strict sense; i. e., for making good the wear and tear of the bodily machinery. The amount needed for this purpose is comparatively small, and is no greater under normal conditions when the animal is doing work than when it is not. Like a good engine, the body makes relatively small demands for repair material and requires chiefly fuel.

Second. Protein as well as ash is needed in the growing, pregnant, or milking animal to furnish the material for enlarging the working machinery of the body of the animal itself or of its young. The amount of protein required for this purpose is just so much in addition to that needed for repair purposes simply, and hence the feed of these animals must contain a more liberal supply of this ingredient. This is important physiologically to secure proper nutrition of the young and economically because the growth or milk produced is the principal object of the feeder.

FEED AS A SOURCE OF REPAIR MATERIAL.

For the reasons stated on page 5, the ash has generally been omitted from consideration in discussing the feed as a source of repair material.

The value of a feeding stuff as a source of protein to the animal body depends in the first place on the amount of protein which it contains. Cottonseed meal, carrying some 43 per cent of protein, is evidently, other things being equal, a better source of protein than Indian corn, carrying about 10 per cent.

In the second place, however, the protein of the feeding stuff must be capable of being digested by the animal. Of two feeding stuffs containing equal amounts of protein, that one is the more valuable as a source of supply in which the larger proportion of the protein is digestible. The second and third columns of the table on pages 11-13 show the average percentages of digestible "crude" and "true" protein contained in a number of the more common feeding stuffs. These figures are the average results of a considerable number of analyses of the feeding stuffs and a smaller number of determinations of their digestibility. Individual samples may vary more or less, and sometimes considerably, from the average.

A third question is at once suggested, viz, whether the digestible protein from different feeding stuffs is equally valuable to the animal. Recent investigations have shown that this is not the case. Single proteins have been found to vary widely in nutritive value, and in particular the mixed proteins of the cereals appear to be of somewhat inferior quality. In ordinary mixed rations, however, it appears doubtful whether these differences are of very much practical significance. At any rate, pending further investigation, the only course which seems open at present is to assume the proteins of the various feeding stuffs to be of substantially equal value.

THE DEMAND FOR FUEL MATERIAL.

Since the animal machinery is running continually, it requires a continual supply of fuel material, the amount which is necessary depending upon the amount of work done. This fuel material consists chiefly of the carbohydrates and fats of the feed, although if more protein be fed than is required for repair and construction purposes it, too, may be used as fuel, while the worn-out portions of the protein tissues are also utilized—that is, the bodily engine can burn up its own waste products as fuel. The unnecessary use of protein as fuel material, however, is wasteful, because protein is ordinarily more expensive to buy or to produce on the farm than are carbohydrates and fats.

If the fuel materials supplied in the feed are just adequate to the work to be done, they are virtually burned up as a source of power. If more are supplied than are immediately needed, the body is able to store away the surplus for future use, much as we may fill up the gasoline tank of an engine. To a small extent the body stores up carbohydrates (in the form of glycogen), but most of its surplus fuel it converts into fat. The fat of the body, therefore, is its reserve of fuel. In fattening, the body is accumulating a surplus against future needs which man diverts to his own use as food. If the feed becomes insufficient, this store is drawn upon and the animal gradually becomes lean. Similarly, in growth and in milk production, the animal sets aside a part of the supply of both repair and fuel material in its feed for its own growth or for the use of its young, and man appropriates the resulting meat or milk as repair and fuel material for his own body.

FEED AS A SOURCE OF FUEL MATERIAL.

We can run an engine with various kinds of fuel. For the steam engine we may use coal or wood or petroleum; for the internal-combustion motor, gas, alcohol, or gasoline may be employed. Similarly, we supply the animal body with a great variety of feeding stuffs from which it has to extract its supply of fuel, and even the materials which it actually burns up are of various sorts.

These fuel materials are not all of equal value. A pound of good anthracite coal, for example, is, other things being equal, about 14 per cent more valuable as fuel than the same weight of alcohol, while a pound of fat in the feed has over twice the fuel value of a pound of starch. Evidently, it will greatly simplify comparisons of different feeding stuffs and rations as sources of fuel material to have some simple method by which we can learn not only the amount of fuel material which the feed contains, but also the quality of that fuel. Such a basis of comparison is afforded by a study of the energy values.

MEASUREMENT OF ENERGY.

Anything which has the capacity to do work is said to possess energy. Hence we say that the fuel of the engine and the feed of the animal possess energy, since they enable the engine or the body to do work. They hold this energy stored up in the "latent" or "potential" form of chemical energy. When they are burned in the engine or the body, this chemical energy is set free, part of it being converted into work and the rest escaping as heat.

Plainly, then, the value of a fuel, or of a feeding stuff so far as it serves as fuel, depends, in the first place, on how much chemical energy it contains. This can be measured without difficulty by con-

verting it all into heat, by burning the substance, and measuring the heat produced. Various units have been employed in measuring heat, but the one used in this bulletin is the therm.

A therm¹ is the quantity of heat required to raise the temperature of 1,000 kilograms (2,204.6 pounds) of water 1° C. A pound of good anthracite coal would produce heat enough to raise the temperature of about 3,583 kilograms of water 1° C. Consequently, the chemical energy contained in the coal is 3.583 therms per pound. In precisely the same way the amount of chemical energy contained in many feeding stuffs has been measured. The following are the results of a few such determinations:

Chemical energy in 100 pounds.²

	Therms.
Timothy hay.....	175.1
Clover hay.....	173.2
Oat straw.....	171.0
Wheat straw.....	171.4
Corn meal.....	170.9
Oats.....	180.6
Wheat bran.....	175.5
Linseed meal.....	196.7

UTILIZATION OF ENERGY.

But the value of a fuel depends also upon how much of the chemical energy which it contains can be used. Hard coal contains plenty of energy, but it would not be of much use to run a gasoline engine. Wheat straw contains fully as much chemical energy as corn meal, but much of that energy can not be utilized by the animal machine.

Two causes combine to affect the utilization of the chemical energy contained in feeding stuffs.

First, more or less of the feed escapes from the body unburned. If a coal is of such quality that portions of it drop through the grate unconsumed, and if smoke and combustible gases are carried off through the stack, it is evident that a ton of it will supply far less heat to the boiler than it would if the combustion were perfect. The case of the feeding stuff is similar. Much of even the best feeding stuffs escapes digestion and is excreted in the dung, carrying with it a corresponding quantity of the chemical energy of the feed. More

¹ In the nutrition investigations and studies of foods and feeding stuffs made by this department and by the State agricultural experiment stations, the results, so far as energy or fuel value is concerned, have been expressed in calories, the unit so used being the large or kilogram calorie, as distinguished from the small or gram calorie. There is consequently a large mass of available data so expressed. The calorie thus used is the amount of heat required to raise 1 kilogram of water 1° C. (approximately 1 pound of water 4° F.). The small size of the unit has made it necessary to use inconveniently large numbers to express the fuel values of foods and feeding stuffs, a difficulty which is obviated by the use of the therm. As the latter unit is equivalent to 1,000 large calories, available data, such, for example, as those in *Farmers' Bulletin 22*, can be readily given expression in the new unit. The use of the word therm, with the abbreviation *t.*, has also been proposed as the equivalent of the small (or gram) calorie, but it has not come into general use.

² With 15 per cent moisture.

or less incompletely burned material is also contained in the urine, while ruminants, and to a certain extent horses and swine, also give off combustible gases arising from fermentations in the digestive tract. Thus about 22 per cent of the chemical energy of corn meal and fully 55 per cent of that of average hay has been found to escape in these ways.

Second, as already pointed out, the animal body has to extract its real fuel material from its feed, separating it from the relatively large proportion of useless material which it excretes. To effect this separation requires work and consumes energy, and this energy, of course, is not available for other purposes. The case is somewhat as if the gasoline engine had to distill its own gasoline and separate it from impurities. Moreover, it appears to be well established that the digestible substances taken up from the alimentary tract act as a direct stimulus to the combustions going on in the body; that is, that the body may burn up more material simply because a larger supply is available, while there is some evidence that an increase in the feed consumed tends to stimulate the minor incidental movements of the animal, or, in other words, to render the animal more restless, especially when standing.

It is not, then, the total chemical energy contained in a feeding stuff which measures its value as fuel material to the body, but what remains after deducting the losses in the unburned materials of the excreta and the energy expenditure incident to the consumption of the feed. This remainder is called its net energy.

For example, while 100 pounds of corn meal contain, as stated, about 170.9 therms of chemical energy, only about 88.8 therms remain, after all these deductions have been made, to represent the actual value of the corn meal as a source of energy to the organism.

NET ENERGY VALUES OF FEEDING STUFFS.

While it is a comparatively simple matter to ascertain the total amount of chemical energy contained in a feeding stuff, the determination of the proportion of this energy which the body can actually utilize, i. e., its net energy value, requires the use of complicated and costly apparatus (respiration apparatus or respiration calorimeter) and the expenditure of much time and labor. While much has been accomplished along this line, vastly more still remains to be done before we can claim to have a complete knowledge of the energy values of feeding stuffs. At the same time, enough has already been accomplished, through the investigations of G. Kühn and of Kellner at the Möckern Experiment Station in Germany, since 1882, and by the experiments carried on, in cooperation with this Department, by the Institute of Animal Nutrition of The Pennsylvania State College, to demonstrate that the method still generally current of

comparing feeding stuffs on the basis of the digestible matter which they contain is seriously erroneous and to permit the computation of at least tentative net energy values. A summary of the results of these investigations has been published in Bulletin 142 of the Pennsylvania Experiment Station together with an outline of the methods used for computing the net energy values of feeding stuffs which have not been the subject of direct experiment.

Henry and Morrison¹ have recently published a very valuable compilation of American analyses of feeding stuffs and of the results of American digestion experiments, and on this basis have calculated the content of digestible nutrients (for ruminants) in a great variety of feeding stuffs.

With the permission of these authors, the writer, in cooperation with Prof. F. S. Putney, of The Pennsylvania State College, has computed from their tables the net energy values of the more important feeding stuffs with the results contained in the following table, which includes the digestible (true) protein and also the nonprotein estimated on the basis of Kellner's averages. In regard to this table it is to be remarked—

First. Both the digestion coefficients used by Henry and Morrison and the data for the expenditure of energy due to feed consumption are derived exclusively from experiments on ruminants (cattle). Consequently, the net energy values here computed are directly applicable to ruminants only.

Second. The table shows primarily the net energy values for maintenance or fattening. There seems good reason for believing, however, that they may be taken without serious error to represent also the net energy values for growth and at least the relative values for milk production. Kellner believes that the same net energy values may also be regarded as expressing with sufficient accuracy the relative values of feeding stuffs for horses and for swine. The requirements for these animals, therefore, as tabulated on the following pages, are substantially those given by Kellner.

¹ Feeds and Feeding, 15th edition, pp. 638-666.

Average dry matter, digestible crude protein, digestible true protein, and net energy values per 100 pounds of feeding stuffs for ruminants.

	Dry matter.	Digestible.		Net energy value.
		Crude protein.	True protein.	
DRIED ROUGHAGE.				
Hay and fodder from cereals.				
	Pounds.	Pounds.	Pounds.	Therms.
Brome grass, smooth.....	91.5	5.0	3.5	40.83
Corn fodder (ears included, medium dry).....	81.7	3.0	2.3	43.94
Corn stover (ears removed, medium dry).....	81.0	2.1	1.6	31.62
Millet, Hungarian.....	85.7	5.0	3.9	46.96
Mixed timothy and clover.....	87.8	5.3	3.2	41.07
Oat hay.....	88.0	4.5	3.9	32.25
Orchard grass.....	88.4	4.7	3.3	44.93
Redtop.....	90.2	4.6	3.9	51.22
Timothy, all analyses.....	88.4	3.0	2.2	43.02
Timothy, before bloom.....	92.8	4.7	2.9	43.52
Timothy, early to full bloom.....	87.2	3.6	2.5	47.40
Timothy, late bloom to early seed.....	85.1	2.4	1.8	37.54
Timothy, nearly ripe.....	87.5	2.2	1.8	38.59
Hay and fodder from legumes.				
Alfalfa, all analyses.....	91.4	10.6	7.1	34.23
Alfalfa, before bloom.....	93.8	15.4	10.3	36.23
Alfalfa, in bloom.....	92.5	10.5	6.7	32.33
Alfalfa, in seed.....	89.6	8.5	6.2	32.23
Clover, alsike.....	87.7	7.9	5.3	34.42
Clover, crimson.....	89.4	9.7	6.9	36.21
Clover, red, all analyses.....	87.1	7.6	4.9	38.68
Clover, red, before bloom.....	89.6	11.6	5.4	42.17
Clover, red, in bloom.....	86.1	8.1	5.3	39.12
Clover, red, after bloom.....	77.9	6.8	4.5	34.51
Clover, sweet white.....	91.4	10.9	6.7	38.98
Cowpeas, all analyses.....	90.3	13.1	9.2	37.59
Cowpeas, before bloom.....	92.2	17.8	12.8	33.54
Cowpeas, in bloom to early pod.....	89.4	12.6	9.5	39.11
Soy beans.....	91.4	11.7	8.8	44.03
Straws.				
Barley.....	85.8	.9	.6	36.61
Buckwheat.....	90.1	4.2	3.2	4.55
Oat.....	88.5	1.0	.8	34.81
Rye.....	92.9	.7	.5	17.59
Wheat.....	91.6	.7	.3	7.22
FRESH GREEN ROUGHAGE.				
Green cereals, etc.				
Barley fodder.....	23.2	2.3	2.0	14.08
Bluegrass, Kentucky, before heading.....	23.8	3.7	2.8	14.82
Bluegrass, Kentucky, headed out.....	36.4	2.8	2.2	17.77
Bluegrass, Kentucky, after bloom.....	43.6	1.9	1.6	21.01
Buckwheat, Japanese.....	36.6	2.2	1.5	17.78
Cabbage.....	8.9	1.9	1.3	8.87
Cabbage, waste outer leaves.....	14.1	1.7	1.1	7.05
Corn fodder, dent, all analyses.....	23.1	1.0	.8	14.60
Corn fodder, dent, in tassel.....	14.9	1.1	.8	9.52
Corn fodder, dent, in milk.....	19.9	1.0	.8	13.64
Corn fodder, dent, dough to glazing.....	25.1	1.3	1.0	17.35
Corn fodder, dent, kernels glazed.....	26.2	1.1	.8	16.74
Corn fodder, dent, kernels ripe.....	34.8	1.5	1.1	22.48
Corn fodder, flint, all analyses.....	20.7	1.0	.8	13.53
Corn fodder, flint, in tassel.....	10.6	.9	.7	6.89
Corn fodder, flint, in milk.....	15.0	.9	.7	10.39
Corn fodder, flint, kernels glazed.....	21.0	1.0	.8	13.49
Corn fodder, flint, kernels ripe.....	27.9	1.2	.9	17.84
Corn fodder, sweet, before milk stage.....	10.0	.8	.6	7.82
Corn fodder, sweet, roasting ears or later.....	20.3	1.2	.9	13.38
Corn fodder, sweet, ears removed.....	21.5	1.0	.8	14.26
Millet, Hungarian.....	27.6	1.9	1.1	17.24
Oat fodder.....	26.1	2.3	2.0	14.06
Orchard grass.....	29.2	1.7	1.1	15.81
Rape.....	16.7	2.6	1.7	13.07
Rye fodder.....	21.3	2.1	1.4	15.99
Sweet sorghum fodder.....	24.9	.7	.4	15.37
Timothy, before bloom.....	24.2	1.8	1.1	18.36
Timothy, in bloom.....	32.1	1.3	.8	18.89
Timothy, in seed.....	46.4	1.5	1.0	26.36
Wheat fodder.....	27.4	2.8	1.9	18.75

Average dry matter, digestible crude protein, digestible true protein, and net energy values per 100 pounds of feeding stuffs for ruminants—Continued.

	Dry matter.	Digestible.		Net energy value.
		Crude protein.	True protein.	
FRESH GREEN ROUGHAGE—continued.				
<i>Green legumes.</i>				
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Threms.</i>
Alfalfa, before bloom.....	19.9	3.5	1.9	9.20
Alfalfa, in bloom.....	25.9	3.3	1.8	11.50
Alfalfa, after bloom.....	29.8	2.1	1.3	11.10
Clover, alsike.....	24.3	2.7	1.5	14.56
Clover, crimson.....	17.4	2.3	1.6	10.83
Clover, red, all analyses.....	26.2	2.7	1.7	15.87
Clover, red, in bloom.....	27.5	2.7	1.8	16.74
Clover, red, rowen.....	34.4	3.3	2.2	17.30
Cowpeas.....	16.3	2.3	1.7	10.42
Peas, Canada field.....	16.6	2.9	2.1	9.78
Soy beans, all analyses.....	23.6	3.2	2.4	12.53
Soy beans, in bloom.....	20.8	3.0	2.3	10.44
Soy beans, in seed.....	24.2	3.1	2.5	12.70
Vetch, hairy.....	18.1	3.5	2.4	11.95
SILAGE.				
Corn, well matured, recent analyses.....	26.3	1.1	.6	15.90
Corn, mature.....	21.0	1.0	.4	11.96
Corn, from frosted ears.....	25.3	1.2	.6	14.27
Corn, from field-cured stover.....	19.6	.5	.3	8.98
Clover.....	27.8	1.3	.8	7.26
Cowpeas.....	22.0	1.8	1.1	11.05
Soy beans.....	27.1	2.6	1.5	11.59
Sugar-beet pulp.....	10.0	.8	.5	9.32
ROOTS, TUBERS, AND FRUITS.				
Apple.....	18.2	.4	.1	15.92
Beet, common.....	13.0	.9	.1	7.84
Beet, sugar.....	16.4	1.2	.4	11.20
Carrot.....	11.7	.9	.5	9.21
Mangels.....	9.4	.8	.1	5.68
Potatoes.....	21.2	1.1	.1	18.27
Pumpkin, field.....	8.3	1.1	.6	6.05
Rutabaga.....	10.9	1.0	.3	8.46
Turnip.....	9.5	1.0	.4	6.16
GRAINS.				
<i>Cereal grains.</i>				
Barley.....	90.7	9.0	8.3	89.94
Buckwheat.....	87.9	8.1	7.2	59.73
Corn, dent.....	89.5	7.5	7.0	89.16
Corn, flint.....	87.8	7.7	7.2	87.50
Corn-and-cob meal.....	89.6	6.1	5.7	75.80
Corn meal.....	88.7	6.9	6.4	88.75
Oats.....	90.8	9.7	8.7	67.56
Oatmeal.....	92.1	12.8	11.5	86.20
Rye.....	90.6	9.9	9.0	93.71
Wheat, all analyses.....	89.8	9.2	8.1	91.82
Wheat, winter.....	89.1	8.7	7.7	91.66
Wheat, spring.....	89.9	9.2	8.1	91.41
<i>Leguminous seeds.</i>				
Bean, navy.....	86.6	18.8	16.4	73.29
Cowpea.....	88.4	19.4	16.9	79.46
Pea, field.....	90.8	19.0	16.6	78.72
Pea meal.....	89.1	19.8	17.2	77.62
Peanut, with hull.....	93.5	19.4	16.9	83.15
Peanut kernel.....	94.0	24.1	22.2	109.04
Soy bean.....	90.1	30.7	27.3	81.29
<i>Oil seeds.</i>				
Cotton seed.....	90.6	13.3	11.9	78.33
Flaxseed.....	90.8	20.6	19.2	83.17
Sunflower seed.....	95.5	23.3	20.2	95.77
Sunflower seed, with hulls.....	93.1	13.5	11.7	92.49

Average dry matter, digestible crude protein, digestible true protein, and net energy values per 100 pounds of feeding stuffs for ruminants—Continued.

	Dry matter.	Digestible.		Net energy value.
		Crude protein.	True protein.	
DAIRY PRODUCTS.				
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Threms.</i>
Buttermilk.....	9.4	3.4	3.4	13.32
Cow's milk.....	13.6	3.3	3.3	29.01
Skim milk, centrifugal.....	9.9	3.6	3.6	14.31
Skim milk, gravity.....	9.6	3.1	3.1	15.43
Skim milk, dried.....	91.7	34.4	34.4	103.91
Whey.....	6.6	.8	.8	10.39
BY-PRODUCTS.				
<i>Fermentation industries.</i>				
Brewers' grains, dried.....	92.5	21.5	20.2	53.38
Brewers' grains, dried, below 25 per cent protein.....	91.8	18.7	17.5	50.93
Brewers' grains, wet.....	24.1	4.6	4.4	14.53
Distillers' grains, dried, from corn.....	93.4	22.4	18.3	85.08
Distillers' grains, dried, from rye.....	92.8	13.6	11.1	56.01
Distillers' grains, wet.....	22.6	3.3	2.8	22.05
Malt.....	94.2	15.8	11.8	87.82
Malt sprouts.....	92.4	20.3	12.5	72.72
<i>Milling.</i>				
Buckwheat bran.....	88.8	10.5	9.1	30.59
Buckwheat hulls.....	89.7	.4	(?)	-7.69
Buckwheat middlings.....	88.0	24.6	20.8	72.19
Hominy feed.....	89.9	7.0	6.5	81.31
Rye bran.....	88.6	12.2	10.5	79.35
Wheat bran.....	89.9	12.5	10.8	53.00
Wheat middlings, flour.....	89.3	15.7	14.0	75.02
Wheat middlings, standard.....	89.6	13.4	12.0	59.10
<i>Oil extraction.</i>				
Coconut meal, low in fat.....	90.4	18.8	18.3	83.49
Coconut meal, high in fat.....	92.3	18.4	18.0	100.31
Cottonseed hulls.....	90.3	.3	(?)	9.92
Cottonseed meal, choice.....	92.5	37.0	35.4	93.46
Cottonseed meal, prime.....	92.2	33.4	32.0	90.00
Germ oil meal, corn.....	91.1	16.5	14.3	83.88
Linseed meal, new process.....	90.4	31.7	30.9	85.12
Linseed meal, old process.....	90.9	30.2	28.5	88.91
Palm-nut cake.....	89.6	12.4	12.0	94.18
Peanut cake from hulled nuts.....	89.3	42.8	41.4	93.55
Peanut cake, hulls included.....	94.4	20.2	19.5	42.57
Soy-bean meal, fat extracted.....	88.2	38.1	37.3	99.65
Sunflower seed, cake.....	90.0	32.0	29.1	88.87
<i>Starch manufacture.</i>				
Gluten feed.....	91.3	21.6	20.1	80.72
Gluten meal.....	90.9	30.2	28.1	84.15
Starch feed, dry.....	90.7	11.2	9.2	77.46
Starch feed, wet.....	33.4	4.1	3.7	30.45
<i>Sugar manufacture.</i>				
Molasses, beet.....	74.7	1.1	.0	57.10
Molasses, cane or blackstrap.....	74.2	1.0	.0	55.38
Molasses, beet-pulp.....	92.4	5.9	3.5	76.28
Sugar-beet pulp, dried.....	91.8	4.6	.7	75.87
Sugar-beet pulp, ensiled.....	10.0	.8	.5	9.32
Sugar-beet pulp, wet.....	9.3	.5	.5	8.99
<i>Packing house.</i>				
Dried blood.....	90.3	69.1	68.6	68.12
Tankage:				
Over 60 per cent protein.....	92.6	58.7	55.6	93.04
55 to 60 per cent protein.....	92.5	54.0	51.1	83.58
45 to 55 per cent protein.....	92.5	48.1	45.5	72.96
Below 45 per cent protein.....	93.5	37.6	35.6	54.16

FEED REQUIREMENTS.

Assuming that the foregoing table represents with a fair degree of accuracy the amount of repair material (protein) on the one hand and of energy on the other which the various feeding stuffs can supply, we still need to know how much of each is required by the bodies of animals of different kinds and kept for different purposes; in other words, we need some formulation of the feed requirements of farm animals.

REQUIREMENTS FOR MAINTENANCE.

Since the animal machine may not be stopped when it is not in active use, it requires, as was pointed out on page 4, and as is a familiar fact of experience, a continual supply of feed. This amount of feed, which is required simply to support the animal, is commonly designated as the "maintenance requirement"—that is, it is the amount required simply to maintain the animal when it is doing no work and producing nothing. In other words, it is the least amount on which life can be permanently maintained.

The maintenance requirement is naturally greater for a large than for a small animal. Experiment has shown, however, that this increase is not proportional to the weight of the animal, but approximately to the amount of surface which it exposes, so that the large animal requires less feed in proportion to its weight to maintain it than does the small one.

The following tables show the amounts of protein and of net energy required per head for the maintenance of cattle, sheep, and horses of different weights. The figures given for sheep include a sufficient allowance for the normal growth of wool. No very satisfactory figures for swine are available. It should be understood that strict accuracy is not claimed for these figures, although they are substantially correct. In particular there seems to be reason to believe that the maintenance requirement of fattening animals increases somewhat more rapidly than these tables indicate.

Maintenance requirements of cattle and horses, per day and head.

Live weight.	Cattle.		Horses.	
	Digestible protein.	Net energy value.	Digestible protein.	Net energy value.
<i>Pounds.</i>	<i>Pounds.</i>	<i>Therms.</i>	<i>Pounds.</i>	<i>Therms.</i>
150	0.15	1.70	0.18	2.10
250	.20	2.40	.24	2.90
500	.30	3.80	.36	4.60
750	.40	4.95	.48	6.00
1,000	.50	6.00	.60	7.30
1,250	.60	7.00	.72	8.50
1,500	.65	7.90	.78	9.60

Maintenance requirements of sheep, per day and head.

Live Weight.	Digestible protein.	Net energy value.
Pounds.	Pounds.	Therms.
20	0.013	0.30
40	.028	.54
60	.039	.71
80	.050	.87
100	.055	1.00
120	.061	1.13
140	.072	1.25

REQUIREMENTS FOR GROWTH.

While young animals gain in weight faster than do older ones, a pound of increase in live weight in the young animal contains much more water and less dry matter than in the case of a more mature animal. Moreover, the dry matter in the case of the young animal contains relatively more protein and less fat, as a rule, than in the older one, and fat contains much more chemical energy than protein, the proportion being 1 to 1.67. The consequence is that a gain of 1 pound in live weight represents the storing up of much less energy in the young than in the mature animal, and therefore requires a smaller supply of energy in the feed.

Unfortunately no very extensive determinations of the composition and energy values of the increase of live weight in growing animals have yet been reported. The following estimates by the writer, derived from such data as are available, may serve to give a general idea of the requirements per pound of growth of cattle and sheep at different ages, but they can not lay claim to any high degree of accuracy. The figures refer to normal growth, with no considerable fattening.

Estimated energy value of 1 pound of gain in weight by growing cattle and sheep.

Age.	Net energy value.
Months.	Therms.
3	1.50
6	1.75
12	2.00
18	2.50
24	2.75
30	3.00

The growing animal also requires a sufficient supply of digestible protein for maintenance and to supply material for new growth. No very systematic study of the latter requirement has yet been made, but from the results of a considerable number of practical feeding trials it is possible to make a fairly satisfactory estimate of the total

amounts of digestible protein which should be contained in the rations of cattle and sheep at different ages to insure satisfactory growth. These estimates are contained in the following table. They are expressed in pounds per head and include the maintenance requirement. As a matter of convenience, the table also contains the estimated net energy values required per head for normal growth, and it thus constitutes a set of approximate feeding standards. In their use the weight rather than the age of the animal should be the controlling factor.

Estimated requirements¹ per day and head.

FOR GROWING CATTLE.

Age.	Beef breeds.			Dairy breeds.		
	Live weight.	Digestible protein.	Net energy value.	Live weight.	Digestible protein.	Net energy value.
<i>Months.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Therms.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Therms.</i>
3	200	0.80	4.2	165	0.65	3.6
6	350	1.10	5.0	275	.85	4.1
9	450	1.25	5.7	325	.90	4.4
12	550	1.40	6.5	400	1.00	5.1
18	750	1.50	8.2	550	1.10	6.4
24	900	1.60	9.3	700	1.20	7.6
30	1,000	1.60	9.9	800	1.20	8.2

FOR GROWING SHEEP.

Age.	Mutton breeds.			Wool breeds.		
	Live weight.	Digestible protein.	Net energy value.	Live weight.	Digestible protein.	Net energy value.
<i>Months.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Therms.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Therms.</i>
6	72	0.31	1.05	65	0.28	0.95
9	98	.27	1.20	82	.23	1.05
12	115	.24	1.35	90	.20	1.15
15	130	.24	1.50	95	.18	1.18
18	150	.23	1.65	100	.15	1.20

¹ Including the maintenance requirement.

No satisfactory data for colts are available, while, as noted on page 10, our knowledge of the relative values of feeding stuffs for swine is somewhat deficient.

REQUIREMENTS FOR FATTENING.

The foregoing data refer to what might be called normal growth, in which the animals are kept in a good thrifty condition, but do not become fat. If any considerable fattening is desirable, somewhat heavier rations must be given in proportion to the amount of gain made, because the increase gain in fattening animals consists to a very large extent of fat and therefore means the storing up by the animal of more reserve energy. For fairly mature fattening ani-

mals—such, for example, as the 2 to 3-year-old steers which are commonly fattened in the corn belt—probably 3.25 therms of net energy per pound of gain in live weight is a fair allowance, although more appears to be often used in practice. As yet no corresponding data are available for the fattening of growing animals, as, for example, in the production of the so-called baby beef. It is not probable, however, that any larger amount of protein is required in such fattening than in feeding simply for normal growth, so that the additional feed given for fattening may, from this point of view, consist largely of nonnitrogenous material; that is, carbohydrates and fats. It is to be noted, however, that an excess of these materials in the ration tends to cause less perfect digestion and also that a moderate proportion of the more nitrogenous concentrates seems to promote the consumption of heavy rations. Kellner recommends that at least 1 pound of digestible protein be supplied in the ration for each 8 to 10 pounds of carbohydrates and fat.

REQUIREMENTS FOR MILK PRODUCTION.

Of all forms of animal production that of milk is perhaps the most variable and most influenced in its amount by the feed supply. The energy relations of milk production have not been very fully investigated. Tentatively, however, it seems safe to estimate that the production of 1 pound of average milk, containing about 13 per cent of total solids and 4 per cent of fat, will require approximately 0.27 therm of net energy value in the feed. Naturally this amount would vary with the quality of the milk, milk rich in fat and in total solids requiring more than milk containing more water or a lower percentage of fat.

The matter of the protein requirements for milk production has not been altogether cleared up. It seems to have been pretty well demonstrated that, for a time at least, a moderate milk production may be kept up on a supply of protein only slightly exceeding that found in the milk produced (of course, in addition to the maintenance requirement). In the case of average milk, this would call for about 0.032 pound of digestible protein for each pound of milk. It has not been demonstrated, however, that a cow can keep this up indefinitely. Furthermore, for the production of liberal yields of milk more protein seems to be required, or at least to be advantageous.

Tentatively, the requirements of digestible true protein and of net energy for the production of 1 pound of milk may be formulated as follows.

Requirements for the production of 1 pound of milk.

Fat in milk.	Requirements.	
	Digestible protein.	Net energy value.
<i>Per cent.</i>	<i>Pounds.</i>	<i>Therms.</i>
2.5	0.041	0.19
3.0	.043	.21
3.5	.045	.24
4.0	.049	.27
4.5	.052	.29
5.0	.055	.32
5.5	.058	.34
6.0	.061	.36
6.5	.064	.39
7.0	.068	.41

REQUIREMENTS FOR WORK.

Since the horse (or mule) is the usual working animal in the United States, consideration will be limited to this animal.

There is on record a considerable amount of data as to the relation between the work performed by the horse and the amount of energy necessary to be supplied in the feed. Where large numbers of horses are kept and the work is relatively uniform in amount, it is possible to make fairly satisfactory computations from these data, although the method is somewhat complicated. The amount of work required of farm horses, however, is so varied in amount and kind and so difficult of measurement or estimate as regards amount, that it is scarcely practicable to base the calculation of rations upon it. The table on pages 11-13 probably shows with at least a fair degree of accuracy the relative values of different feeding stuffs as sources of energy for work production, while the amount to be fed will ordinarily be based upon the observation of the feeder rather than upon arithmetical calculations. As a sort of general average, however, Kellner recommends the following rations for a 1,000-pound horse, the amounts stated including the maintenance requirement:

Requirements of the working horse.

	Digestible protein.	Net energy value.
	<i>Pounds.</i>	<i>Therms.</i>
For light work.....	1.0	9.80
For medium work.....	1.4	12.40
For heavy work.....	2.0	16.00

DRY MATTER IN RATIONS.

The total volume of feed which an animal requires, although rather variable, has its limits. In computing rations the most convenient indication of the bulk of the feeds is the percentage of dry

matter shown in the first column of the table on pages 11-13. In very general terms it may be said that a 1,000-pound ruminant should be given from 20 to 30 pounds of dry matter per day, 25 pounds being perhaps a fair average, while for the horse smaller amounts will be appropriate.

A study of the table shows that concentrated feeding stuffs contain much more protein and energy in proportion to their dry matter than do the forage crops. Evidently, then, in heavy feeding, where the purpose is to give the animal all the feed possible, the ration should consist as largely as practicable of concentrated feeding stuffs, because only in that way can the required amount of nutriment be obtained without unduly increasing the bulk of the ration. On the other hand, in light feeding the coarse fodders may predominate, because they are usually relatively cheaper and can supply the required amount of nutriment in a bulk which the animal can consume.

THE COMPUTATION OF RATIONS.

GENERAL CONSIDERATIONS.

In the foregoing pages we have considered the requirements of the animal machine for repair material (protein), and for fuel material (energy), and have also studied the feed as a source of these two. If we knew exactly the requirements of the animal in any given case, and if we knew exactly what amounts of protein and energy the feeding stuffs at our disposal could furnish, the computation of a ration would be almost purely a matter of arithmetic. We would simply have to devise a mixture of the feeding stuffs which would yield the requisite amounts of protein and energy and would at the same time be of suitable bulk and of such a character as to exert no injurious action upon the animal.

As a matter of fact, we have no such exact knowledge. Practically, animals vary in their requirements, while feeding stuffs of the same name show a wide range in composition, digestibility, and nutritive value. Furthermore, what is still more important, the economic conditions vary from case to case so that, for example, a very liberal ration might be advisable in one instance, while for the same animal under different conditions it would be highly uneconomic. The figures given on previous pages can not be made the basis of infallible recipes which shall save the user the trouble of observing and thinking.

But notwithstanding all this, the foregoing data can afford valuable aid to the feeder. By their use he can get a general idea of the feed requirements of his animals and can compute a ration which will approximately supply the requisite amounts of protein and energy. His ability as a feeder will be shown, first, in his power

to estimate the conditions which will modify the feed requirements of his particular animals and cause his feeds to vary from the average, and, second, in the skill with which he can interpret the daily results and modify his feeding in accordance with them.

The problems given on the following pages are intended simply as illustrations of the method of using the tables and not as model rations. Limitations of space forbid the multiplication of examples, but the reader who grasps the method will have no serious difficulty in applying it to his own conditions, while facility will be acquired with surprising rapidity by practice. It will be observed that the form of these tables and the methods of computation do not differ materially from those which have been used for many years in computing rations on the basis of "digestible nutrients," although the significance of some of the figures is different. It may be added that the digestible protein in the tables is true protein—that is, it does not include the so-called "amids" of the "crude protein." Consequently the percentages, as well as the amounts estimated in the rations on succeeding pages, are somewhat smaller than in the older tables.

TOTAL FEED REQUIRED.

A bunch of "feeders" 2 to 3 years old, averaging 1,000 pounds per head and in better than average condition, are to be fattened on clover hay and corn-and-cob meal. Such cattle, if of good grade, should weigh 1,400 pounds each when ready for market and should not require over 200 days to make the gain of 400 pounds. They should therefore make an average gain of 2 pounds per day.

It may be estimated that a gain of 1 pound live weight by animals of this grade will require about 3.5 therms of net energy value in the feed; for a daily gain of 2 pounds, therefore, the requirement would be 7 therms. To this must be added the maintenance requirement, which will increase as the animals grow heavier. For the average weight of 1,200 pounds it is sufficiently accurate to use the maintenance requirement computed in the table on page 14 for 1,250 pounds, viz, 7 therms. This makes the total net energy requirement per day 14 therms on the average of the whole feeding period.

If we assume that 2 pounds of grain will be fed for each pound of hay, it is easy to compute from the figures in the last column of the table on pages 11–13 the amount of feed required to supply 14 therms of net energy, as follows:

	Therms.
In 100 pounds of average clover hay.....	33.68
In 200 pounds of corn-and-cob meal.....	151.60
In 300 pounds of feed.....	190.28
In 1 pound of feed.....	.634

To supply 14 therms requires $14 \div 0.634 = 22.08$ pounds of total feed, consisting of 7.36 pounds of clover hay and 14.72 pounds of corn-and-cob meal, or, in round numbers, $7\frac{1}{2}$ pounds of hay and 15 pounds of meal.

This, of course, represents the average ration for the whole feeding period. At the beginning the feed will naturally be lighter and consist to a larger extent of hay, while the amount of feed, and especially the proportion of grain, will be gradually increased until toward the end of the feeding the animals are consuming all the grain they will take, with only enough hay to insure the necessary bulk and proper digestion. Naturally, too, the form in which the corn is given will usually be varied in the course of the feeding.

IMPROVEMENT OF A RATION.

In the foregoing example it was assumed that the feeding stuffs to be used had been decided upon and attention was directed simply to the quantity required. Let us now take up the question from the other end and see whether a study of the ration may not yield some suggestion of possible improvement.

According to the table on pages 11-13, clover hay and corn-and-cob meal, respectively, contain in 100 pounds—

Feed.	Total dry matter.	Digestible protein.	Net energy value.
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Therms.</i>
Clover hay.....	87.1	4.9	38.68
Corn-and-cob meal.....	89.6	5.7	75.80

The $7\frac{1}{2}$ pounds of clover hay in the ration will evidently contain:

$$87.1 \times 0.075 = 6.53 \text{ pounds of dry matter.}$$

$$4.9 \times 0.075 = 0.37 \text{ pound of digestible protein.}$$

$$38.68 \times 0.075 = 2.90 \text{ therms of net energy value.}$$

A precisely similar computation for the corn-and-cob meal gives the following results:

$$89.6 \times 0.15 = 13.44 \text{ pounds of dry matter.}$$

$$5.7 \times 0.15 = 0.85 \text{ pound of digestible protein.}$$

$$75.8 \times 0.15 = 11.37 \text{ therms of net energy.}$$

Adding these amounts, we find that the total ration contains:

Kind and amount of feed.	Total dry matter.	Digestible protein.	Net energy value.
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Therms.</i>
Clover hay, $7\frac{1}{2}$ pounds.....	6.53	0.37	2.90
Corn-and-cob meal, 15 pounds.....	13.44	.85	11.37
Total.....	19.97	1.22	14.27

The quantity of energy, of course, corresponds with that estimated to be necessary, because the amounts of feed were fixed upon on that basis. We observe, however, that the amount of digestible protein in the ration is less than is estimated on page 16 to be needed by beef cattle of this age. A ration like the above might produce fair gains, but it probably would fail to take full advantage of the capacity of such cattle for growth and the gain would most likely fall below that which was anticipated. An increase in the protein could be expected to make the ration more efficient.

To make any marked change in the ration in this respect, it is evident that we must introduce into it some feed much richer in protein than either of those composing it. On consulting the table it is evident that what we need is one of the by-product feeds like gluten feed or meal, the oil meals, etc., and also that only a small amount of one of these will be needed to effect a marked change in the ration. Thus, if we substitute 2 pounds of old-process linseed meal for 2 pounds of the corn-and-cob meal, the ration will foot up as follows:

Kind and amount of feed.	Total dry matter.	Digestible protein.	Net energy value.
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Therms.</i>
Clover hay, 7½ pounds.....	6.53	0.37	2.90
Corn-and-cob meal, 13 pounds.....	11.65	.74	9.85
Old-process linseed meal, 2 pounds.....	1.82	.57	1.78
Total.....	20.00	1.68	14.53

Thus at a comparatively small additional expense we are able to improve the ration materially by adding the lacking protein, and there is little doubt that the improved ration would produce a more rapid gain and, under ordinary conditions, a more profitable one as well, either by increasing the total gain or shortening the feeding period.

COMPUTING A RATION FROM GIVEN FEEDING STUFFS.

There are available for a dairy herd field-cured corn forage (including the ears), clover hay, corn meal, wheat bran, and gluten feed. The table on pages 11-13 shows that these feeding stuffs, if of good average quality, will furnish in 100 pounds:

Feed.	Total dry matter.	Digestible protein.	Net energy value.
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Therms.</i>
Corn forage.....	81.7	2.3	43.94
Clover hay.....	87.1	4.9	38.68
Corn meal.....	88.7	6.4	88.75
Wheat bran.....	89.9	10.8	53.00
Gluten meal.....	90.9	28.1	84.15

The cows average 850 pounds per head and have produced in previous years an average of 20 pounds of milk per day testing 4 per cent of fat. According to the table on page 14, the maintenance requirement of such animals per day and head would be approximately—

Digestible protein.....	pound..	0.43
Net energy.....	therms..	5.40

For the production of 20 pounds of 4 per cent milk there would be needed, according to the estimates on page 18:

Digestible protein (0.05×20).....	pound..	1.0
Net energy (0.27×20).....	therms..	5.4

The total feed requirements per day and head are therefore:

	Digestible protein.	Net energy value.
	<i>Pounds.</i>	<i>Therms.</i>
For maintenance.....	0.43	5.40
For milk production.....	1.00	5.40
Total.....	1.43	10.80

The problem, then, is to find a mixture of the available feeding stuffs which will yield these amounts of digestible protein and of energy, and which shall have a suitable bulk.

The first step in the construction of a ration is to fix upon the amounts of coarse fodders. It is usually desirable to use as large a proportion of these as possible, since they are usually cheaper sources of food than grain. On the other hand, the amount of them which an animal can consume is limited. Much depends upon the individual animals, and the proper amount can only be told by trial, but we should probably aim to get from 12 to 14 pounds of dry matter in the form of coarse fodder. Corn forage being a cheap feeding stuff, we shall naturally use this freely, with probably some hay for variety. By a little trial, we find that 10 pounds of corn forage and 6 pounds of clover hay will give us 13.4 pounds of dry matter and the amounts of digestible protein and of energy shown below:

Kind and amount of feed.	Total dry matter.	Digestible protein.	Net energy value.
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Therms.</i>
Corn forage, 10 pounds.....	8.17	0.23	4.39
Clover hay, 6 pounds.....	5.23	.29	2.32
Total.....	13.40	.52	6.71

To this we have to add sufficient grain to bring the ration up to the requirement. The proper amount we must ascertain by trial. We will take, at a venture, 4 pounds of corn meal and 2 pounds of wheat bran. Adding this to the ration we have:

Kind and amount of feed.	Total dry matter.	Digestible protein.	Net energy value.
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Therms.</i>
Corn forage, 10 pounds.....	8.17	0.23	4.39
Clover hay, 6 pounds.....	5.23	.29	2.32
Corn meal, 4 pounds.....	3.55	.26	3.55
Wheat bran, 2 pounds.....	1.80	.22	1.06
Total.....	18.75	1.00	11.32

Comparing these totals with the requirement as computed, we find that the ration is ample as regards energy but considerably low in digestible protein. The rather low figure for dry matter shows that more feed may be added to the ration if desirable, but the total for net energy makes it evident that what is needed is not more feed, but feed of a different composition, supplying more protein along with rather less energy. Gluten meal answers this requirement, and substituting 2 pounds of it for 2 pounds of corn meal gives a ration which, while still a trifle high in energy, agrees as closely as necessary with the computed requirements. Thus:

Kind and amount of feed.	Total dry matter.	Digestible protein.	Net-energy value.
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Therms.</i>
Corn forage, 10 pounds.....	8.17	0.23	4.39
Clover hay, 6 pounds.....	5.23	.29	2.32
Corn meal, 2 pounds.....	1.77	.13	1.78
Wheat bran, 2 pounds.....	1.80	.22	1.06
Gluten meal, 2 pounds.....	1.82	.56	1.68
Total.....	18.79	1.43	11.23

This ration corresponds with the average requirement of the whole herd, since it is based on its average performance. It hardly need be said that it should be modified to suit the requirements and capacities of the individual cows, the heavy milkers getting more and the lighter ones less.

By proceeding in this manner, with a little patience we can usually get a ration corresponding as closely as is necessary to the requirement, provided the feeds available admit of it. With a little experience one very soon learns to guess pretty closely, and with some practice the computations become very easy. An exact agreement with the requirement need not be sought for, since in practice the composition of the feeds will probably vary more or less from the average of the tables.

THE CHOICE OF FEEDING STUFFS.

When, as in the last example, feeding stuffs must be purchased in order to get the desired relation between the protein and the energy of the ration, it is evident that often a wide range of choice may be offered. In such a case the question at once arises which of the various feeds available is it most economical to purchase, it being evident of course, that this is not necessarily the one offered at the lowest price.

No simple method of determining this point is possible, because, as we have seen, the feed serves two entirely distinct purposes in the body. Sometimes the supply of protein is the specially important point, and in other cases what is needed is a supply of energy without special reference to whether its source be protein or nonnitrogenous material. Consequently, the relative values of two feeding stuffs may vary under different circumstances. Some writers have based their comparisons of the values of by-product feeds solely upon their content of protein, for the reason that such feeds are often bought especially to supply this ingredient, while the fats and especially the carbohydrates are usually produced in abundance upon the farm. They regard that purchased feeding stuff as the most economical which furnishes a pound of digestible protein at the lowest cost, ignoring any value in the other ingredients. It is obvious, however, that this is a one-sided view. The other ingredients have a value, and this is especially true in the case of a feeder who buys a considerable part of his grain supply and depends upon it as a source of energy as well as of protein. The method of comparison illustrated in the following pages is based primarily upon the cost per unit of energy because this is on the whole the most important function of the feed, but the method takes account also of the amount of protein present.

Let us suppose the following feeding stuffs are available to a dairyman at the prices named:

Prices of feeds per ton.

Oats (40 cents per bushel).....	\$25
Corn meal.....	25
Wheat bran.....	21
Wheat middlings (flour).....	24
Dried brewers' grains.....	23
Gluten meal.....	27
Cottonseed meal (prime).....	30
Old-process linseed meal.....	33

The supply of coarse feed on the farm is sufficient to furnish each animal per day 32 pounds of silage and 8 pounds of clover hay; the cows average 1,000 pounds each and may be expected to produce per day about 24 pounds of milk testing 4.5 per cent fat.

The first step is to compute, in precisely the same way as in the previous example, the estimated requirements of these cows per day as follows:

	Digestible protein.	Net-energy value.
	<i>Pounds.</i>	<i>Therms.</i>
For maintenance.....	0.50	6.00
For 24 pounds of milk:		
Protein 24×0.052	1.25	.....
Net energy 24×0.29		6.96
Total requirement.....	1.75	12.96

The amount of silage and clover hay available will furnish, according to the table on pages 11-13, the following amounts of dry matter, digestible protein, and net energy value:

Kind and amount of feed.	Total dry matter.	Digestible protein.	Net energy value.
	<i>Pounds.</i>	<i>Pound.</i>	<i>Therms.</i>
Corn silage, 32 pounds.....	8.42	0.19	5.09
Clover hay, 8 pounds.....	6.97	.39	3.09
Total.....	15.39	.58	8.18

The question now is what feeding stuffs is it most economical to buy (or to refrain from selling if in stock) to complete the ration. The first step in deciding this question is to compare the various feeds as sources of energy and see which one furnishes a unit of net energy value at the lowest price. This computation gives the following results:

Kind of feed.	Cost of 100 pounds.	Energy value of 100 pounds.	Cost of 1 therm net energy value.
		<i>Therms.</i>	<i>Cents.</i>
Oats.....	\$1.25	67.56	1.85
Corn meal.....	1.25	88.75	1.41
Wheat bran.....	1.95	53.00	1.98
Wheat middlings.....	1.20	75.02	1.60
Dried brewer's grains.....	1.15	53.38	2.15
Gluten meal.....	1.35	84.15	1.60
Cottonseed meal.....	1.50	90.00	1.67
Old-process linseed meal.....	1.65	88.91	1.86

Evidently, if it were simply a question of supplying energy to the animals, we should use corn meal, since that supplies a unit of energy at a much lower price than any of the other feeding stuffs. If it were thought desirable to add variety to the ration, wheat middlings would obviously be our next choice.

It is evident, however, without going through the labor of computation, that while corn meal and wheat middlings may be used in the ration, neither will supply enough protein if used exclusively. Of the available feeding stuffs which are rich in protein and which may therefore serve to balance the deficiency of this ingredient, gluten meal is relatively the cheapest, and cottonseed meal comes next. While the difference between the two is not great, we shall naturally try the cheaper one. It is not difficult to determine by a few trials that $2\frac{1}{2}$ pounds of corn meal and $3\frac{1}{2}$ pounds of gluten meal, in addition to the coarse fodder available, will give a ration corresponding very closely to the requirements, as the following table shows:

Kind and amount of feed.	Total dry matter.	Digestible protein.	Net energy value.
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Therms.</i>
Corn silage, 32 pounds.....	8.42	0.19	5.09
Clover hay, 8 pounds.....	6.97	.39	3.09
Corn meal, $2\frac{1}{2}$ pounds.....	2.22	.16	2.22
Gluten feed, $3\frac{1}{2}$ pounds.....	3.18	.98	2.95
Total.....	20.79	1.72	13.35

This ration shows as close an agreement with the computed protein requirement as could be desired, but contains a slight surplus of energy. The comparatively low figure for dry matter indicates that more coarse fodder might have been used had it been available, with the probable effect of cheapening the ration. As it is, we have used the feeds relatively lowest in price and apparently have a very economical ration.

Cottonseed meal, however, is nearly as cheap as a source of energy as gluten meal, while it contains considerably more protein. It seems worth while, therefore, to see whether it may not be possible to secure the necessary protein more cheaply by using a smaller amount of the former feed in place of the gluten meal. Three pounds of cottonseed meal will supply almost exactly the same amount of protein as $3\frac{1}{2}$ pounds of gluten meal. Making this substitution, the ration stands as follows:

Kind and amount of feed.	Total dry matter.	Digestible protein.	Net energy value.
	<i>Pounds.</i>	<i>Pounds.</i>	<i>Therms.</i>
Corn silage, 32 pounds.....	8.42	0.19	5.09
Clover hay, 8 pounds.....	6.97	.39	3.09
Corn meal, $2\frac{1}{2}$ pounds.....	2.22	.16	2.22
Cottonseed meal, 3 pounds.....	2.77	.96	2.70
Total.....	20.38	1.70	13.10

This ration agrees with the computed requirements even better than the previous one, while a simple comparison shows that it is actually a trifle cheaper. The grain portion of the two rations costs as follows:

Feed in ration.	First ration.	Second ration.
	<i>Cents.</i>	<i>Cents.</i>
Corn meal.....	3.13	3.13
Gluten meal.....	4.73	
Cottonseed meal.....		4.20
Total.....	7.86	7.33

It thus appears that the ration made up with the somewhat more expensive cottonseed meal is actually the cheaper. The difference, to be sure, is small, yet for 30 cows fed for 200 days it would amount to \$30. Such a difference is only likely to be found, however, when, as was assumed in this instance, some feed very high in protein can be had at a relatively cheap rate. In general, it may be said that when there are no very marked differences in the cost of a therm of energy value in the feeding stuffs constituting the bulk of the ration one of the various high-protein feeds which supplies energy at the lowest cost should ordinarily be used, although it is always wise to check up this point, as in the example just given.

THE COMPOUNDING OF RATIONS.

While in the foregoing examples an exact daily ration is computed, it would, of course, be utterly impracticable in most cases to weigh out separately each day's ration for each animal. Individual weighings of feeds at intervals would often yield valuable information and might be profitably undertaken, but for the ordinary routine of feeding simpler methods must be used.

When practicable, the grain feed may be advantageously mixed in advance in the desired proportions in as large quantities as the storage capacity available and the proper preservation of the materials will permit. Where facilities are available, the whole amount of grain required for all the animals may be weighed out daily, or even for each feeding, without much additional labor. In distributing the grain to the individual animals, regard of course should be paid to their productive capacity and their individual peculiarities. The ration, as computed, is for the average animal. The skill of the feeder is shown in adapting it in quality and in amount to the individual. Doubtless individual weighings at intervals, as already suggested, would be useful as a control on the accuracy of the distribution.

The weighing of coarse fodder is usually a more difficult problem on account of its bulk. When, however, silage or cut fodder is handled in trucks, the matter is still comparatively simple. Long fodder, on the contrary, is not readily weighed. Nevertheless, even here an occasional weighing, if practicable, as a control upon the feeding, is very desirable.

In all these and similar matters common sense is necessary. The computed ration expresses the best estimate that can be made of the actual average requirements, but it is at best more or less of an approximation. It would be foolish, therefore, to seek extreme exactness in realizing it or to go to more expense in the weighing and apportioning of the feed than the saving in the latter would amount to. The scale upon which the feeding is conducted will play an important part. Where scores or hundreds of animals are being fed, an exactness may be profitably sought which would be absurd in the case of two or three animals. Finally, it should be remembered that these computed rations are guides and not recipes. They may aid the feeder in wisely using the resources at his command, but they can not take the place of experience and good judgment.

BEARING ON FARM MANAGEMENT.

The data and the methods of computation on previous pages will aid the feeder in determining the amounts of each class of feeds needed for each class of his animals. The man of good business habits will find them useful in determining the quantities of each kind of feed to grow or purchase and in deciding upon the purchase of animals to feed and the feeds to keep or to purchase for feeding them. These facts and methods will aid the farmer, the feeder, or the user of work animals in deciding upon the chances of profit in proposed enterprises. Often by using these formal ways of checking up a proposed business project the way is made more clear to avoid loss and to secure the largest practicable profit. In case of the farmer who grows most of his feed stuffs, these facts and methods of calculation may often be used in connection with the planning of his scheme of crop rotation and in proportioning the acreages of the respective crops to each other and to the numbers of each class of animals. They will prove useful in reducing the farm-management plan to a scientific basis.

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BULLETIN No. 460

Contribution from the Forest Service.
HENRY S. GRAVES, Forester.



Washington, D. C.

PROFESSIONAL PAPER

May 26, 1917

THE PINE TREES OF THE ROCKY MOUNTAIN REGION.

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SCOPE OF THE BULLETIN.

In this bulletin are described and figured the distinguishing characteristics of all of the pine trees that inhabit the Rocky Mountain region. Graphic illustrations of the range of these trees and discussions of their forest habits are also included. The exact limits of the Rocky Mountain territory covered by this publication are given in Bulletin No. 207¹ of the Forest Service, to which the reader is referred. Other statements made there regarding the general plan of treating the subject, sources of information, and acknowledgments of assistance² received apply to the present bulletin. The

¹ "The Cypress and Juniper Trees of the Rocky Mountain Region, 1915.

² Grateful acknowledgment is here made to Dr. H. N. Whitford for valuable notes on the range of *Pinus manticola* and *P. albicaulis* in British Columbia.

reader will also find full information in Bulletin 207 regarding the class and family relationship of the pines to other coniferous trees of the Rocky Mountains.

GENERIC CHARACTERISTICS OF PINES.

All of the pines are evergreen trees, their branches being more or less thickly clothed with clusters of leaves which are needlelike and borne in bundles or fascicles of 1, 2, 3, 4, or 5.¹ When the leaves first appear, they have a basal sheath of scales, in some cases very thin and in others thicker and stiff. In some pines these scales are retained until the leaves die, while in others they are shed when the leaves become fully grown. The leaves vary in length from about 1 to 15 inches. The juvenile or primordial form of leaf borne on the first shoot of seedling pines differs from the adult form by being single, this form soon being followed by adult or true foliage leaves. Seed-leaves (cotyledons) of pines, the first foliar organs produced when the seed germinates, are needle-shaped and from 3 to 15 in number. The leaves of pines vary from cylindrical, as in the single-leaved species, and half-round, as in two-leaved pines, to a triangular or three-edged leaf in the 3- to 5-leaved species. The edges of the leaves of some pines are provided with minute teeth, while those of others are smooth. The color of the leaves ranges from a blue or silvery green to a deep yellow-green, the surfaces bearing lines of minute pores or stomata. In cross section the leaves of pines show from 2 to 14 minute resin ducts, the position and number of which vary in different species. A new set of leaves is formed each year on the young twigs. The leaves produced each season may remain on the tree from 2 to 6 or 8 years, during which they maintain their green color and vegetative activity. When a set of new leaves is being formed at the ends of the new twigs, the oldest set of leaves, situated farther back on the branches, dies and falls to the ground. The winter buds of pines are variable in form and in size, and all are covered by fringed or papery-margined overlapping scales. The component scales each protect a tiny bud, which, when the main bud unfolds in the spring, develops into a fascicle of leaves or, in some cases, into a female flower.

The flowers of the pines are male and female, borne usually on different branches of the same tree. Male flowers, which produce pollen, are short, oval, and budlike, or long cylindrical bodies, clustered at the ends of mature leafy branches. In color they are bright

¹ Remarkable variations occur in the generally regular number of leaves borne by the 2- 3- 4- and 5-leaved pines, a 2- or 3-leaved species occasionally or frequently having a number of 3- and 4-leaved fascicles, while the 4- and 5-leaved pines may have some fascicles with 5, 6, or 7 leaves. Whether or not these variations represent gradual transitions from one type to a different type of foliar habit can not be affirmed at present.

red, yellow, or orange. The female flowers, which produce cones and seed, are small, greenish, scaly, conelike bodies, produced singly or in pairs or larger groups near the ends of young growing shoots. After fertilization of one or both of the two ovules (under each scale) the female flowers develop into small cones during the first season, completing their growth at the end of the second or third summer.

The fruits of pines are woody, scaly cones, matured in 2 or 3 years. Each of the scales in the central portion of the cone usually bears 2 seeds at its base and on the under side. The cones of some pines remain on the trees only a few weeks after ripening, while those of others persist for many years; or they may be so firmly attached that finally they become entirely enveloped by the annual diameter growth of the branch or trunk and never leave the tree. Within a few weeks after maturity most pine cones open under the heat of the sun and liberate their seeds. The cones of a few pines, however, may remain closed for several or for many seasons, sometimes opening fully only under the heat of a forest fire. The cones of one of our pines (*Pinus albicaulis*) never open naturally, the seeds not being liberated until the scales rot by contact with the ground. This peculiar retention of the seeds explains in part at least how certain pines often reproduce themselves after the original forest has been killed by fire, since not all of the cones are burned enough to destroy their seeds, which are scattered after the fire.

Mature cones vary in length, according to the species, from an inch to 2 feet, and in diameter from three-fourths of an inch to 6 or 8 inches. The seeds of most pines bear a thin papery wing at one end, the wing assisting greatly in the distribution of the seed (Pl. I, *c*, *d*). In a few species, however, the seeds have only the rudiment of a wing, which remains attached to the cone scales, thus rendering the seed wingless when it is shed (Pl. X, *e*). The piñon or "nut" pines bear wingless seeds, which, unlike winged seeds, are dependent for their distribution on such accidental agencies as flood waters and mammals. Pine seeds vary in size from one-half that of a kernel of wheat to nearly the size of a small hazelnut.¹

The pines are among our most important commercial trees. Most of them have straight, unbranched, cylindrical trunks, which furnish large amounts of excellent saw timber. On account of the straight grain, strength, and other qualities of pine timber it is used for nearly every sort of construction work.

The large quantities of naval stores used in the United States, or exported to other countries, are derived by distillation from the crude

¹ Pine seeds are the favorite food of many birds, and of squirrels and other rodents, which doubtless consume large quantities. Seeds of the "nut" pines are also gathered extensively by western Indians and settlers for food. Mammals, however, often assist in distributing pine seeds through their habit of caching the seeds in the ground where those not eaten may later germinate.

resin of the heavy, more resinous-wooded pines. All of the pines yield resin in greater or less quantities, but so far the commercial qualities of only a few of these resins have been determined. In recent years the wood of pine stumps and old logs is also being distilled for turpentine, this product being known as wood turpentine.

Some 70 species of pines are known in the world. Thirty-six of them inhabit the United States, 14 of which occur in the Rocky Mountain region. Six of these Rocky Mountain species occur also in the Pacific slope region, and one ranges eastward from the Rockies in Canada into the Atlantic coast country.

Pines are of ancient origin, some of them having existed in North America and Europe in the Cretaceous and Miocene periods.

WHITE PINES.

Trees with light, soft wood in which the early and late formed portions of the annual rings are not sharply defined.

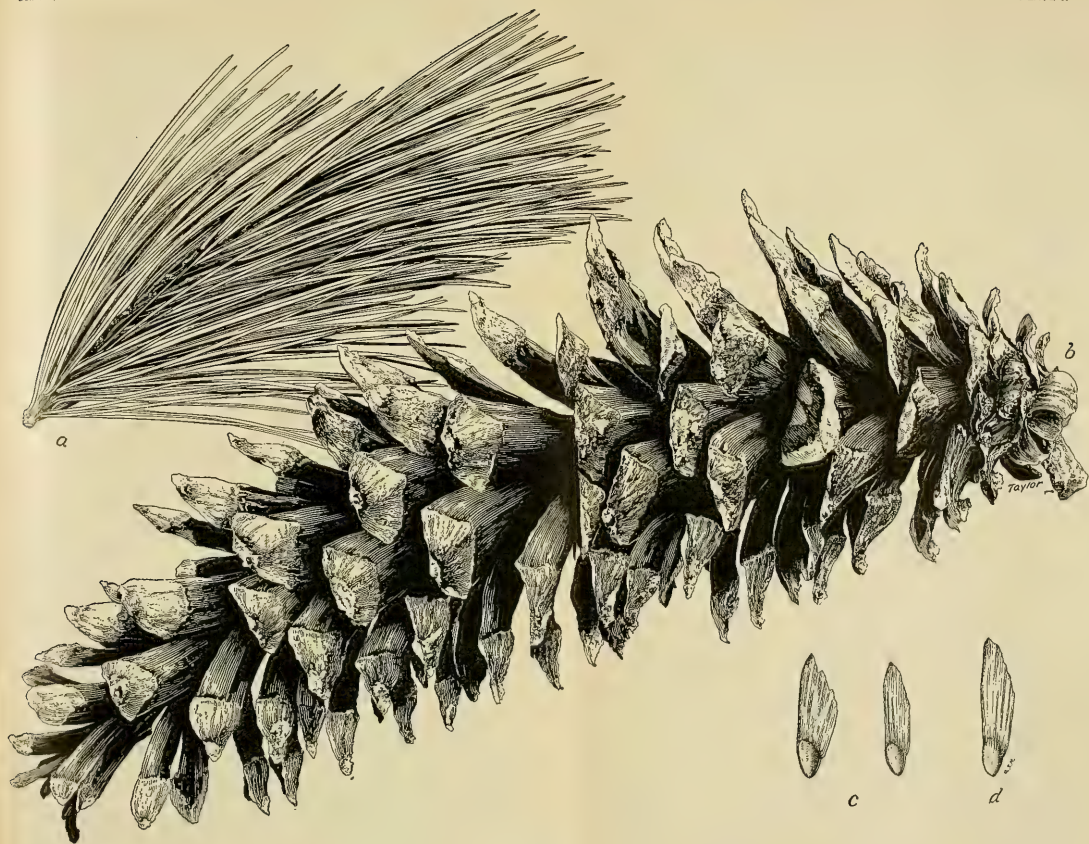
WESTERN WHITE PINE.

Pinus monticola Douglas.

COMMON NAME AND EARLY HISTORY.

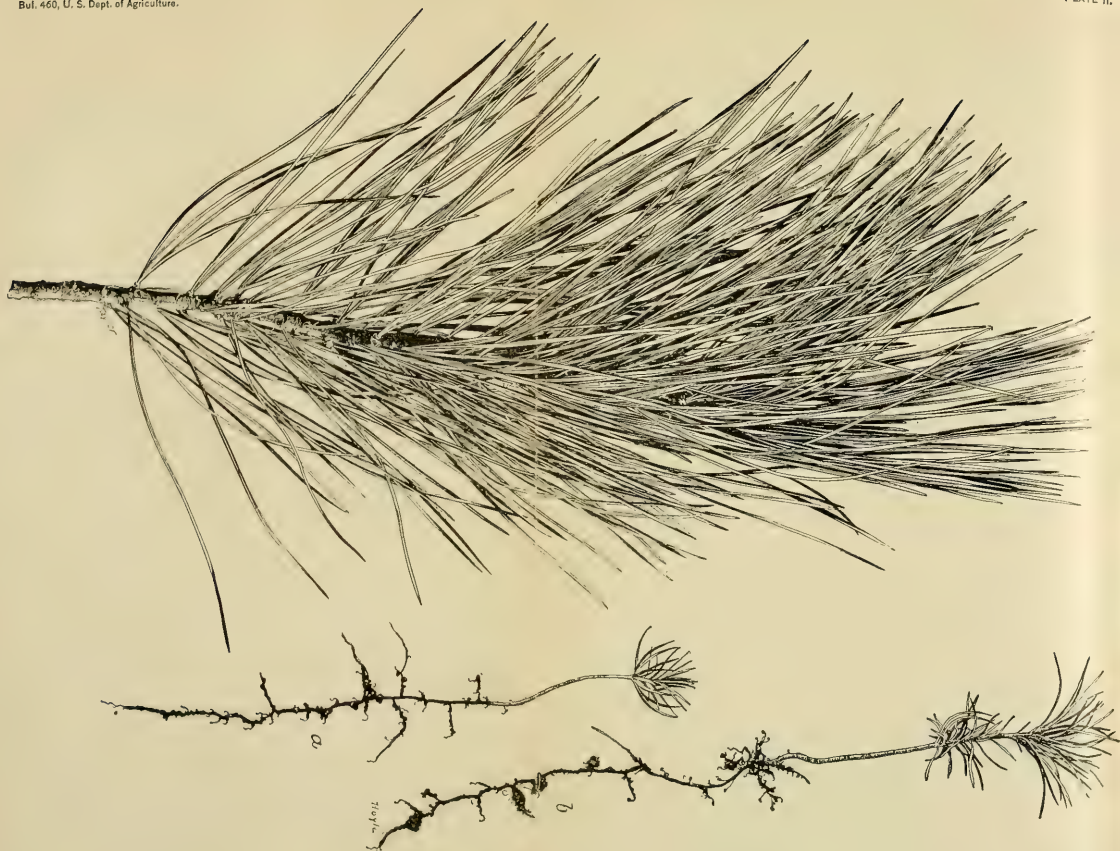
Pinus monticola is now properly known as western white pine. It is hoped that this name may be widely accepted in order to avoid confusing *Pinus monticola* with its eastern relative, *Pinus strobus*. For a number of years it was known to western lumbermen and manufacturers as "Idaho white pine" and "Montana white pine," because the commercial supply of lumber came from forests in northern Idaho and northwestern Montana. It is also called "white pine," probably on account of the similarity of its wood to the well-known white pine (*Pinus strobus*) of northeastern United States and adjacent Canadian territory. The book names "silver pine," referring to the silvery-green hue of the foliage, and "mountain Weymouth pine," based partly on the tree's technical name and partly on an English name for *Pinus strobus*, are not in current use.

Western white pine was discovered by that redoubtable Scotch explorer of our Northwest, David Douglas, who found it in 1831 near the Columbia River, whether in Oregon or Washington is unknown, but probably in Washington. The tree was technically described and named for the first time in 1837. The name then given to it, *Pinus monticola*, has been generally maintained and there has been little or no confusion of the western white pine with other white pines of its range. Because of its general resemblance to the eastern white pine (*Pinus strobus*), Nuttall described it in 1849 as a variety (*Pinus strobus* β *monticola*) of this species, from which, however, it is distinct. In 1888 and 1895 Dr. J. G. Lemmon distinguished two varie-



PINUS MONTICOLA.

a, Foliage; b, detached cones; seeds with wings; c, upper side; d, lower side.



PINUS MONTICOLA: FOLIAGE.
a, b, one- and two-year-old seedlings.

ties of the western white pine, *Pinus monticola minima* and *P. monticola digitata*, based on differences he recognized in the form and size of the cones. A purple-coned form of western white pine cultivated in England was described in 1866 as *Pinus porphyrocarpa* A. Murray, and later, in 1892, as *Pinus monticola* variety *porphyrocarpa* Masters. In the writer's judgment, none of these forms are worthy of specific or varietal distinction.¹

DISTINGUISHING CHARACTERISTICS.

In dense forests, where its most characteristic form is found, this pine has a tall, slender shaft, with a peculiarly short-branched, narrow, symmetrical crown. The branches are usually slender and drooping, and in early life extend over one-half or two-thirds the length of the trunk. Its height ranges from 90 to 150 feet, and its diameter from $2\frac{1}{2}$ to 5, or exceptionally, from 6 to 8 feet. In open forests, where the conditions of growth are less favorable to its better development, western white pine is a short-bodied tree, 50 or 60 feet in height, with one or more very long, stout, horizontal branches extending from 10 to 15 feet or more beyond the other slender branches. This striking characteristic distinguishes the tree as far as it can be seen.

The bark of trees a foot or more in diameter is distinctly broken into small, square blocks. No other tree associated with it has this bark characteristic. The bark of mature trees is rarely over $1\frac{1}{4}$ inches thick. In dense stands the color of the bark is grayish purple, while in open, windswept stands it is a distinct cinnamon-brown. The fierce winds of such locations constantly tear off the thin outer scales of bark and expose the red-brown interior. Young trees have thin, smooth, bright gray bark, as do also the branches and upper stems of old trees. The scaly winter buds are about one-half an inch long. During the first year the young twigs are deep yellowish brown and minutely hairy, but during the second year they become smooth.

The foliage of this pine is bluish green with a whitish tinge. That produced each season remains on the twigs until the third or fourth year. The leaves are from 2 to about 4 inches long and are borne in bundles of 5 (Pl. I, *a*; Pl. II). Their margins have minute widely separated teeth. The foliage of trees grown in exposed situations is

¹ Western white pine was introduced into England by David Douglas shortly after he discovered it in 1831. According to Elwes and Henry (Trees of Great Britain and Ireland, V, 1024, 1910) it was not common in cultivation there until 1851 or 1855. While perfectly hardy in England as regards cold, these authors find that it grows best in Scotland, particularly in moister situations. The largest trees planted in England are from 76 to 81 feet in height and from 20 to 32 inches in diameter. Some of these trees were planted as early as 1834 and 1847. *Pinus monticola* thrives in northeastern United States, where it has been planted as far north as western New York (Wyoming County) and eastern Massachusetts.

denser (Pl. I, *a*) than that on trees in protected places or in close stands (Pl. II). A cross section of the leaf shows one or two resin ducts centrally situated near the border (back of leaf).

The cones are matured at the end of the second summer, usually by the first of September. They shed their seed soon afterward and fall from the trees within a few months. Mature cones (Pl. I, *b*) vary in length from about 6 to 10 inches: occasionally they are slightly longer or shorter. Before the mature cones become weathered by exposure the tips of the scales are red-brown or yellow-brown, the inner portion of the scales being a deep red. The seeds (Pl. I, *c, d*) are reddish brown, with small blackish spots. The seed-leaves vary in number from 6 to 9 (Pl. II, *a, b*).

The wood of western white pine is soft and of very light weight, a cubic foot of dry wood weighing about 24 pounds. The sapwood is nearly white and the heartwood is pale brown. The wood is very similar in appearance and in its working qualities to the wood of the eastern white pine (*Pinus strobus*), for which it is now extensively substituted.

OCCURRENCE AND HABITS.

Western white pine is not confined to any definite type of locality, but it occurs at an elevation of from about 2,000 in moist valleys, where it grows largest, to about 7,000 feet in dry, exposed, subalpine regions, where the trees are much smaller (Map No. 1). It is adapted to a variety of soils. The best growth, however, occurs where they are deep and porous. Regionally, the greatest development of western white pine is in northern Idaho and in adjacent parts of north-western Montana, on gentle north slopes and flats. Lodgepole pine, Englemann spruce, western larch, western red cedar, alpine fir, grand fir, alpine hemlock, and western yew are variously associated with it in different parts of its range.

Western white pine endures considerable shade for a relatively long period during its seedling and later young growth, after which it requires abundant top light for its best development. Saplings or pole forms of the tree do not recover and grow well after they have been long suppressed by the shade of older trees.

This pine is not a prolific seeder. It bears cones only when about from 40 to 60 years old and at irregular intervals of about two years. As a rule, it reproduces itself sparingly. Seed germinates poorly on heavy humus, unless the latter is thoroughly and constantly moist: the best germination occurs on exposed, moist, mineral soil.

LONGEVITY.

Western white pine is a long-lived tree, attaining an age of from 200 to 500 years.

LIMBER PINE.

Pinus flexilis James.

COMMON NAME AND EARLY HISTORY.

Pinus flexilis is generally known in its mountain habitat as "white pine"; but as this name properly belongs to *Pinus strobus* of north-eastern United States, the common name "limber pine," coined from the tree's technical name, *flexilis*, has been adopted. This name appropriately refers to the marked flexible quality of the twigs.

Limber pine was found first in 1820 near timber-line at the base of Pike's Peak, Colo., by Dr. Edwin James, a United States Army surgeon and naturalist attached to Stephen Harriman Long's expedition to the Rocky Mountains. Dr. James was also the first to name and describe this tree, his account of it being published in 1823. Since that time the botanical history of limber pine has been moderately free from confusion with related white pines of its range.¹

DISTINGUISHING CHARACTERISTICS.

Pinus flexilis is a comparatively little-known species, doubtless because it grows chiefly in high places difficult of access. It is a low, thick-trunked, much-branched tree, from 25 to 50 feet in height, or sometimes 80 feet, with a short trunk from 12 to 30 inches in diameter; occasionally very old trees are from 3½ to 4 feet in diameter. Young trees are peculiar for their regular distinct whorls of short, very tough branches, which stand out at right angles to the trunk and extend down to the ground. Middle-aged and old trees (from 75 to 200 years old) are characterized by extremely long and slender branches, especially near the ground and at the top; the latter are often 16 or 18 feet long and droop gracefully at a sharp angle with the trunk. These branches appear to develop entirely at the expense of the trunk, which remains stunted.

Large trunks have blackish or very dark-brown bark, which is from 1½ to nearly 2 inches thick and deeply furrowed between the wide rectangular blocks; on trunks from 8 to 12 inches thick the bark is broken into small, thin, gray-brown plates. When separated, the scales expose a dull reddish inner bark. The thin, smooth bark of young pole-size trees and of branches is a bright whitish-gray, often

¹ Dr. C. C. Parry is said to have been the first to introduce this pine into cultivation, plants having been raised in the Harvard Botanic Garden from seed he collected in Colorado in 1861. The tree is possibly not adapted to our eastern climate, for the trees raised from Dr. Parry's seed attained a height of only about 5 feet in 35 years. Further planting of the tree at the Letchworth Park Forest and Arboretum, Wyoming County, N. Y., will later throw light upon this question. It appears to be better adapted to the climate of England, where, according to Elwes and Henry (*The Trees of Great Britain and Ireland*, V, 1048, 1910), three trees in Kew Gardens, probably grown from Dr. Parry's seed, had reached a height of 32 feet and about 11 inches in diameter in 1910. Other smaller trees planted in England are growing thriflily.

silvery. The exceedingly tough twigs are at first covered with fine, soft hairs, which soon disappear, leaving the branchlets quite smooth.

The dark yellow-green foliage is densely set at the ends of the branches. The leaves, borne in clusters of 5 (Pls. III, IV, V), are from about $1\frac{3}{4}$ to nearly 3 inches long. Each year's growth of leaves persists for approximately 5 years, a few sometimes remaining until the sixth year. The margins of the leaves bear minute widely separated teeth. A cross section of the leaf shows two resin ducts (on the back of the leaf) near the border; sometimes also there is a third resin duct near the inner or lower border of the leaf. The back (dorsal) side of the leaves is marked by from 1 to 4 lines of minute pores (stomata).

The cones (Pls. III to V) are mature in late summer or early autumn of the second year, and shed their seed in September or early in October. They are from $3\frac{1}{2}$ to 10 inches long and peculiar in having the tips of their light yellowish-brown scales greatly thickened (Pl. III, *c*). The inner or concealed portions of the scales are pale red. By early winter the cones have fallen from the trees (Pls. III, *a*; IV, *a*). The seeds (Pl. III, *b*) are deep reddish brown and speckled with blackish brown. The seed-leaves are usually from 6 to 8 or sometimes 9 in number (Pl. V, *a*).

The wood of limber pine is very narrow-ringed, on account of the slow growth of the tree, and has only a thin layer of sapwood, which is nearly white. Freshly cut heartwood is a pale lemon-yellow. In texture the wood is rather soft but firm. A cubic foot of dry wood weighs about 27 pounds. Limber pine is occasionally cut for rough construction lumber which is used locally, the quality of the lumber being poor because of numerous knots. The wood is also used locally for fuel and sometimes for rough cabins and mine props.

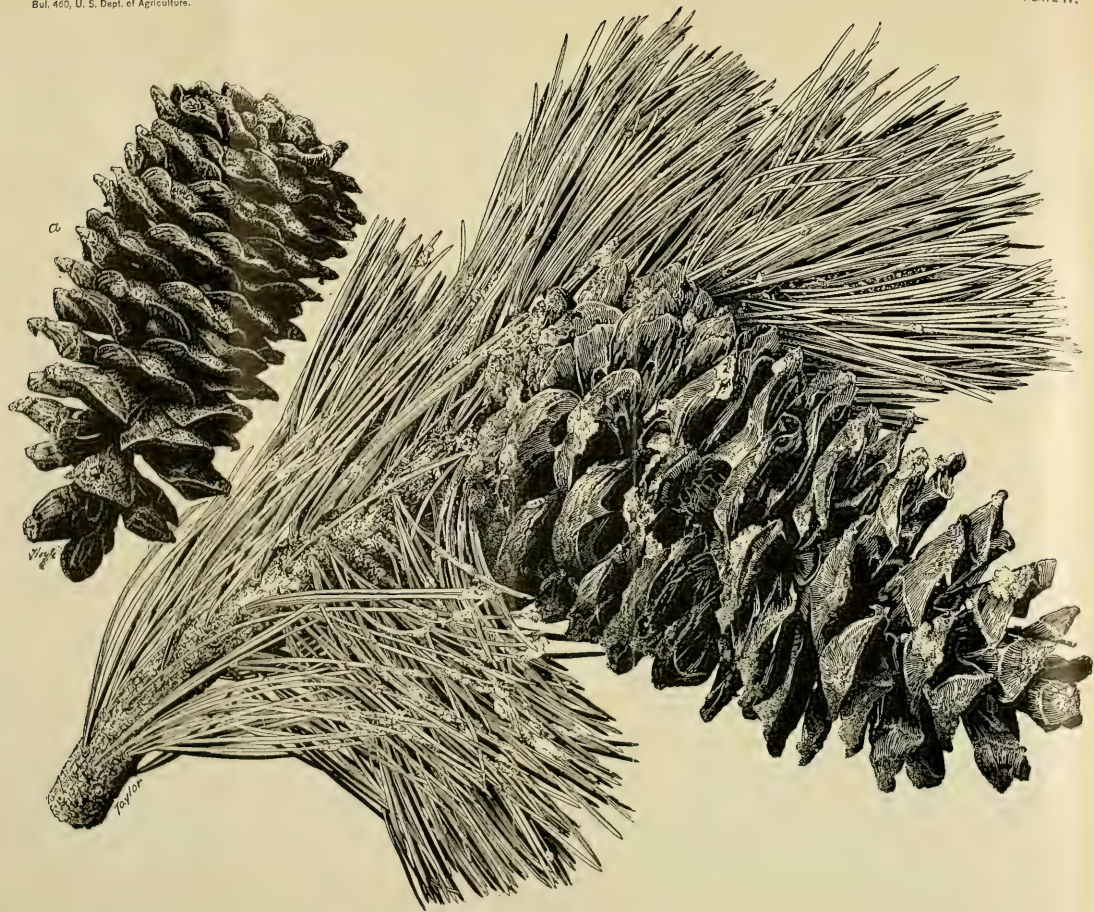
OCCURRENCE AND HABITS.

Limber pine grows on dry, rocky, east slopes, summits, tops of ridges and foothills, and sometimes on the sides of moist canyons and banks of mountain streams, at elevations between 5,000 and 12,000 feet (Map No. 2). It is adapted to a great variety of soils and is not exacting as regards their depth or the amount of moisture, though it grows best in moist, well-drained soils. Usually it occurs in dry, rocky, very shallow soil, appearing to prefer dry gravelly loam with little or no humus. Limber pine reaches higher elevations on clay soils than it does on sandy ones, the higher ascent in clay soils being due to their greater retentiveness of moisture, which is especially favorable to seedling growth. This species is of much more frequent occurrence in the Rocky Mountain region than in the Pacific region.



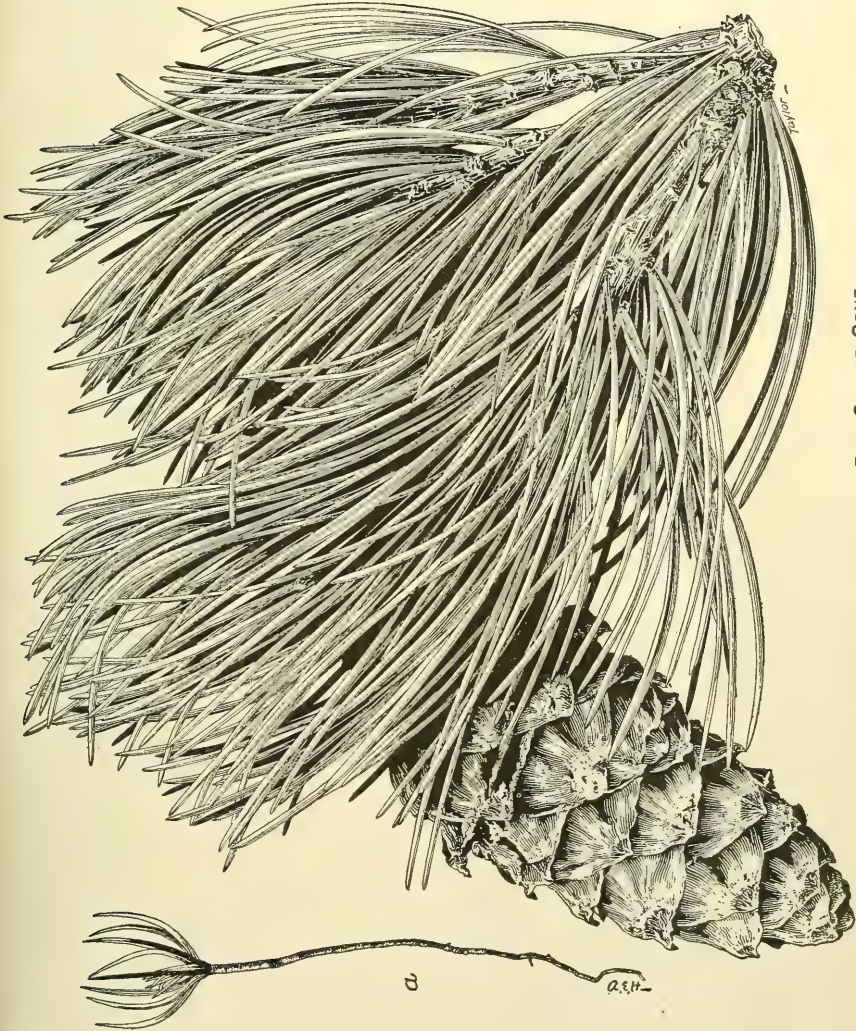
PINUS FLEXILIS: FOLIAGE AND LARGE FORM OF OPEN CONES (ATTACHED).

a, Detached small form of open cone; b, upper side of cone scale with its seeds; c, lower side of cone scale



PINUS FLEXILIS: FOLIAGE AND LARGE FORM OF OPEN CONE,

a, Detached small form of open cone,



PINUS FLEXILIS: FOLIAGE AND RIPE CLOSED CONE.
a, Seedling one month old (slightly less than natural size).

Pinus flexilis usually occurs interspersed among other conifers, singly or in small groves, the largest size being produced under these conditions. Occasionally, however, it forms pure, open growths of stunted trees on exposed slopes and ridges. It is associated mainly with lodgepole pine and mountain hemlock at higher elevations, and sparingly with white fir and Douglas fir at lower altitudes.

Limber pine grows best only in the full enjoyment of light, never forming dense stands. It is similar in its requirements of sunlight to the white-bark and bristle-cone pines, being less able to grow in the shade, except when young, than other associated conifers. Limber pine is not an aggressive tree and rarely crowds out other species. It is a moderate seeder, the amount of seed borne varying with the region and elevation. Generally it bears the largest number of cones in open stands at low altitudes, fruiting less abundantly in the denser stands and at higher elevations. The cones are produced locally about every year, while good seed years occur at intervals only of several years. Many of the seeds are eaten by birds and squirrels before they are shed. They are practically wingless and fall only near the trees. Flood waters distribute the seeds irregularly and the "hoards" of pine squirrels occasionally result in accidental planting of uneaten seed. Germination of the seed, which at best is only moderate, occurs most abundantly in moist mineral soil.

LONGEVITY.

Little is known now of the longevity of this pine. Trees from 18 to 22 inches through are from 200 to 300 years old.

WHITE-BARK PINE.

Pinus albicaulis Engelm.

COMMON NAME AND EARLY HISTORY.

This species is commonly known to lay travelers in its high mountain habitat only as "scrub pine," because of its stunted form in exposed, wind-swept places. Those who know it botanically, however, usually call it white-bark pine, a name derived from the tree's technical name, *albicaulis* (white stem), which has reference to the characteristic chalky-white color of the bark.

Pinus albicaulis was discovered in 1851 by the intrepid Scotch botanical explorer, John Jeffrey. A letter he wrote, now preserved at the Royal Gardens of Edinburgh,¹ states that he found the tree "on the summit of a mountain near Fort Hope, Fraser's River," central British Columbia, at an elevation of 7,000 feet. A. Murray,

¹ Fide Sargent, Silva, XI, 41, 1897.

a Scotch botanist, published the first account of the tree in 1853 under the name *Pinus flexilis*, confusing it with the limber pine, which was discovered and named 20 years before. Likewise, in 1857, Dr. Newberry erroneously referred to it as *Pinus cembroides*. It remained for Dr. George Engelmann to describe this pine technically and to establish its present name, *Pinus albicaulis*, in 1863. The French botanist Carrière named it *Pinus shasta* in 1867, while as late as 1880 Dr. Engelmann, then concluding that it was a closely related form of the limber pine, renamed it *Pinus flexilis* var. *albicaulis*. As now known, however, the white-bark pine is specifically distinct from our other white pines.¹

DISTINGUISHING CHARACTERISTICS.

White-bark pine has a low, long-branched, twisted, or crooked trunk from 15 to 50 feet high and from 10 to 24 inches in diameter. Taller and larger trees occur in protected situations. In the higher wind-swept places it is often reduced to a sprawling shrub with enormous branches spreading over the ground. Young trees have distant, regular whorls of branches which stand out at right angles to the trunk, but in later life some of the upper whorls of branches develop upward into long, willowy stems, giving the tree a loose, bushy crown. The branches, especially near the trunk, are exceedingly tough and flexible, so that the tree is able to withstand the fiercest storms without being broken.

The bark, even of old trees, is little broken, except near the base of the trunk, where it is rarely more than one-half of an inch thick. Here narrow cracks divide the bark into very thin whitish or brownish scales, which when torn off reveal the characteristic red-brown inner bark. Elsewhere the bark is rarely more than one-fourth of an inch thick. Twigs of a year's and sometimes of two years' growth are slightly downy.

The dark yellow-green leaves (Pl. VI), densely clustered at the ends of the branches, are borne in bundles of 5, and are from about $1\frac{1}{2}$ to $2\frac{3}{4}$ inches long. Shorter leaves occur on trees in the most exposed situations (Pl. VI, *d*). The margins of the leaves are commonly smooth, but sometimes they have very widely separated minute teeth. A cross section of the leaf shows two resin ducts (centrally located on the dorsal or back side of leaf); occasionally a third resin duct occurs on one of the lower sides. The leaves of each season's

¹ White-bark pine was probably first introduced into cultivation in Scotland through the seeds John Jeffrey is said to have sent there from Mount Shasta, California, in 1852 (see Elwes and Henry, op. cit., 1049). Elwes and Henry state that no plants appear to have survived, and that the only specimens now known (1910) are seedlings growing in Kew Gardens. It is probable that, like the limber pine of similar habitat, the white-bark pine can not be successfully grown in eastern United States. However, it is in no way attractive as an ornamental tree.

growth remain on the tree for approximately 7 or 8 years, but some of them for only 4 or 5 years. The cones (Pl. VI, *a*, *b*) mature by the end of August or early in September of the second year. At this time they are a deep purple. They have very thick scales, and vary in length from about $1\frac{1}{2}$ to nearly $3\frac{1}{2}$ inches. Rarely, if ever, do the cone scales become separated sufficiently to liberate the nutlike seeds (Pl. VI, *c*). As a rule, while the cones are still on the trees, and long before they are ready to fall, practically the entire crop of seeds is devoured by mountain squirrels and such birds as Clark's crow. The birds get the seeds by tearing away the cone scales; squirrels very cleverly extract all of the seeds by cutting a hole in one side of the cone (Pl. VI, *a*). The few cones that remain unopened on the trees and finally reach the ground gradually become loosened and broken by decay; then the seeds fall out or germinate in the rotted remains of the cones. The seeds (Pl. VI, *c*), about half an inch in length by one-third of an inch in diameter, have very narrow wings, which remain attached to the cone scales when the seeds fall out or are extracted; the thick, hard shell of the seeds is dark chocolate-brown. The seed-leaves of this species vary in number from 7 to 9.

The wood of the white-bark pine is rather soft, but firm in texture, and when dry very brittle. It has only a thin layer of whitish sapwood. The heartwood is pale brown when freshly cut. Owing to the exceedingly slow growth of the tree, the wood is very narrow-ringed. A cubic foot of dry wood weighs approximately 26 pounds. Prospectors occasionally use logs from this tree for cabins, for timbering "prospect holes," and for fuel.

OCCURRENCE AND HABITS.

Pinus albicaulis is confined to rather narrow altitudinal limits on alpine slopes and exposed ridges at elevations between 5,000 and 12,000 feet (Map No. 3). It grows among broken bare rocks, in disintegrated granite, and in shallow rocky soils with little superficial moisture, the best growth, however, being in well-drained, moist soil.

White-bark pine sometimes occurs in pure open stands on grassy areas, but usually in open, parklike growth, preferably on north slopes with alpine fir, Engelmann spruce, Lyall larch, limber pine, and lodgepole pine. Perhaps its most characteristic occurrence is in scattered clusters of from three to seven trees, which appear to grow as from the same root.

Pinus albicaulis is somewhat intolerant of shade in youth, becoming still less tolerant with age. It appears to be more intolerant in the North than in the South. In the South it shows a preference for north slopes. Greater tolerance of shade is shown on good moist soils at low altitudes than on poor dry ones near timber line.

In general white-bark pine is a good seeder, but seed production varies greatly with the region and locality. In the North it seeds only at long intervals, while in the South it bears seed frequently. Reproduction is rather scanty, this doubtless being due in part to the large quantities of seed eaten by birds and squirrels. Because the seeds are carried to the ground in the heavy unopened cones, reproduction is confined mainly to the vicinity of seed trees. Being unprotected by the mother trees, seedlings that come up in exposed places are often damaged by winds, which whip the stems about so that they are sometimes worn in two at the collar by rubbing against the rough granite soil.

LONGEVITY.

White-bark pine is moderately long-lived, attaining an age of from 250 years (when it may be about 19 inches in diameter) to 325 years. Very few records of the tree's longevity are available.

MEXICAN WHITE PINE.

Pinus strobiformis Engelm.

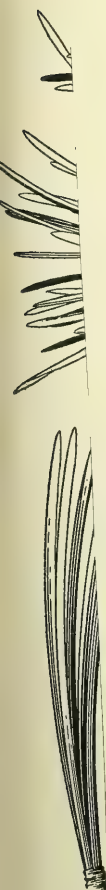
COMMON NAME AND EARLY HISTORY.

This little-known species is without a distinctive common name, being known only as "white pine." The name "Mexican white pine" is suggested because the greater part of the tree's range is in Mexico, its range in the United States being very limited (Map No. 4).

Mexican white pine was discovered in Chihuahua, Mexico, in 1846 by Dr. A. Wislizenus. Twenty-six years after its discovery in Mexico Dr. J. T. Rothrock found it in the Santa Rita Mountains, Arizona. The first description and the technical name of it were published in 1848. The botanical history of Mexican white pine shows that the tree was little understood until about 25 years ago. In 1868 a French author referred to it as *Pinus ayacahuite*, which is another Mexican species; in 1878 Dr. Engelm. named a form of it *Pinus flexilis*, γ *reflexa*, which four years later (1882) he ranked as a distinct species, *Pinus reflexa*. Under this name Mexican white pine was chiefly known to American botanists until 1889, when Prof. C. S. Sargent¹ pointed out that Engelm.'s *Pinus reflexa* and *P. strobiformis* refer to the same tree, the latter name being the older.

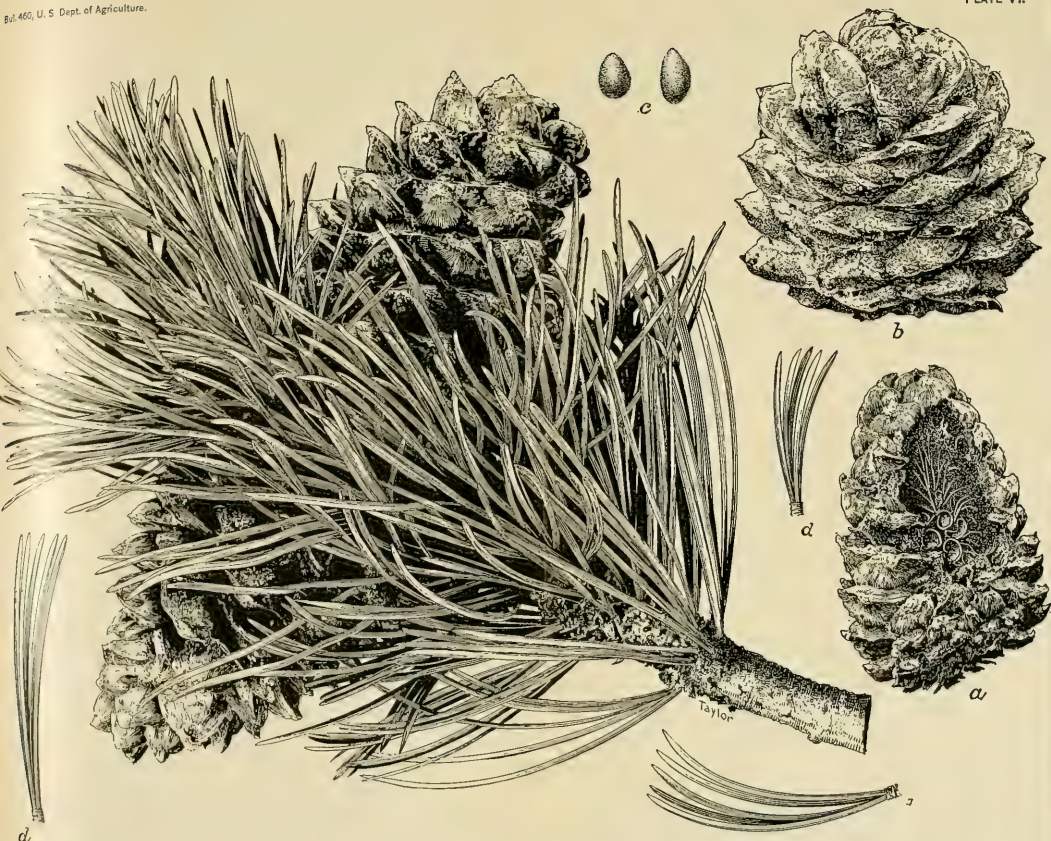
Recently Dr. G. R. Shaw² reduced this species to "*P. ayacahuite* var. *brachyptera* Shaw." For the present, however, the writer prefers to

¹ Gard. and For. II, 496, 1889. ² The Pines of Mexico, Pl. vi, p. 11, 1909.



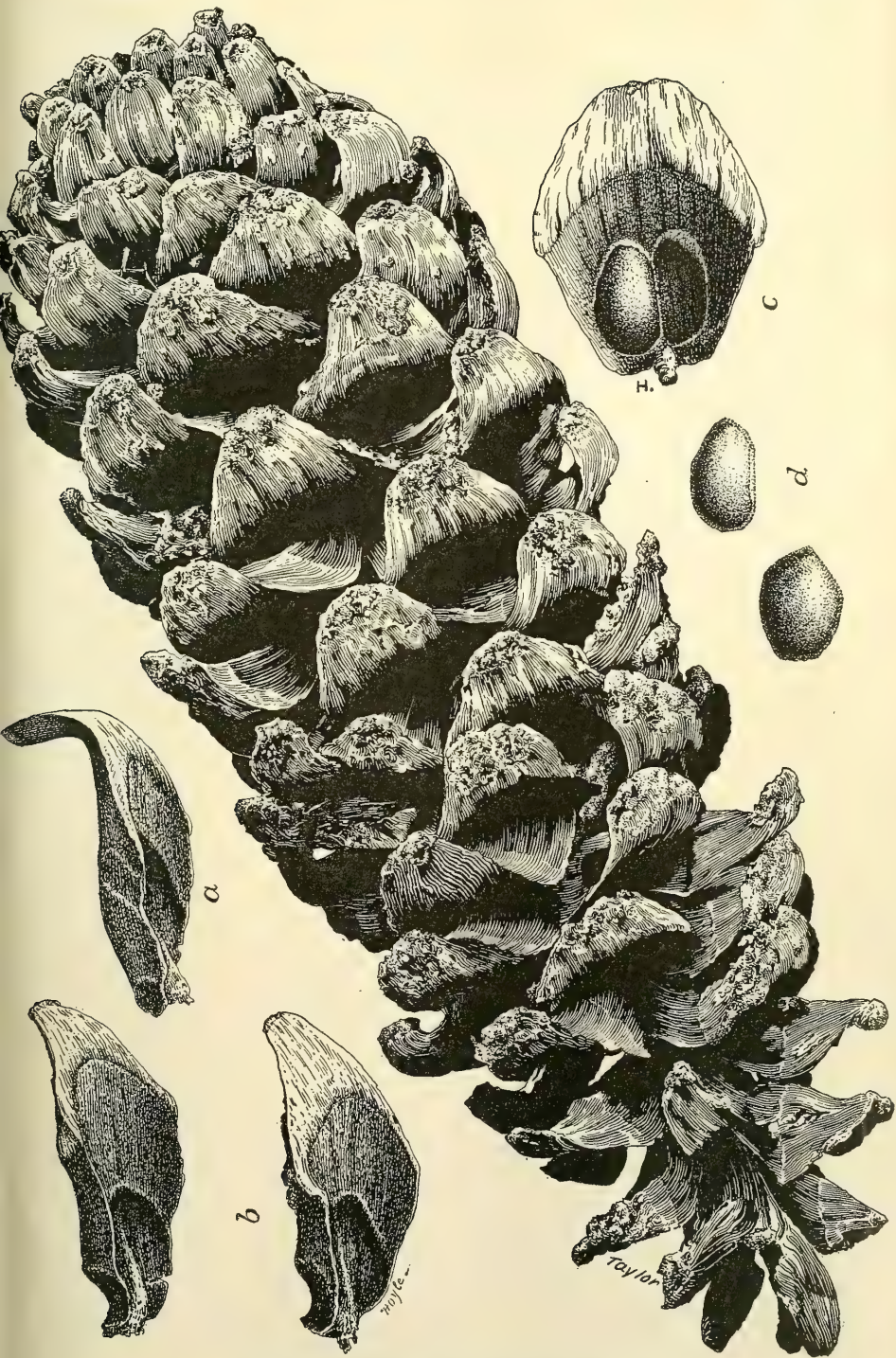
d





PINUS ALBICAULIS: FOLIAGE AND CONES.

a, Detached cone, from which a squirrel has cut out the seeds; b, detached cone; c, seeds; d, detached leaf bundles, showing variation in length.



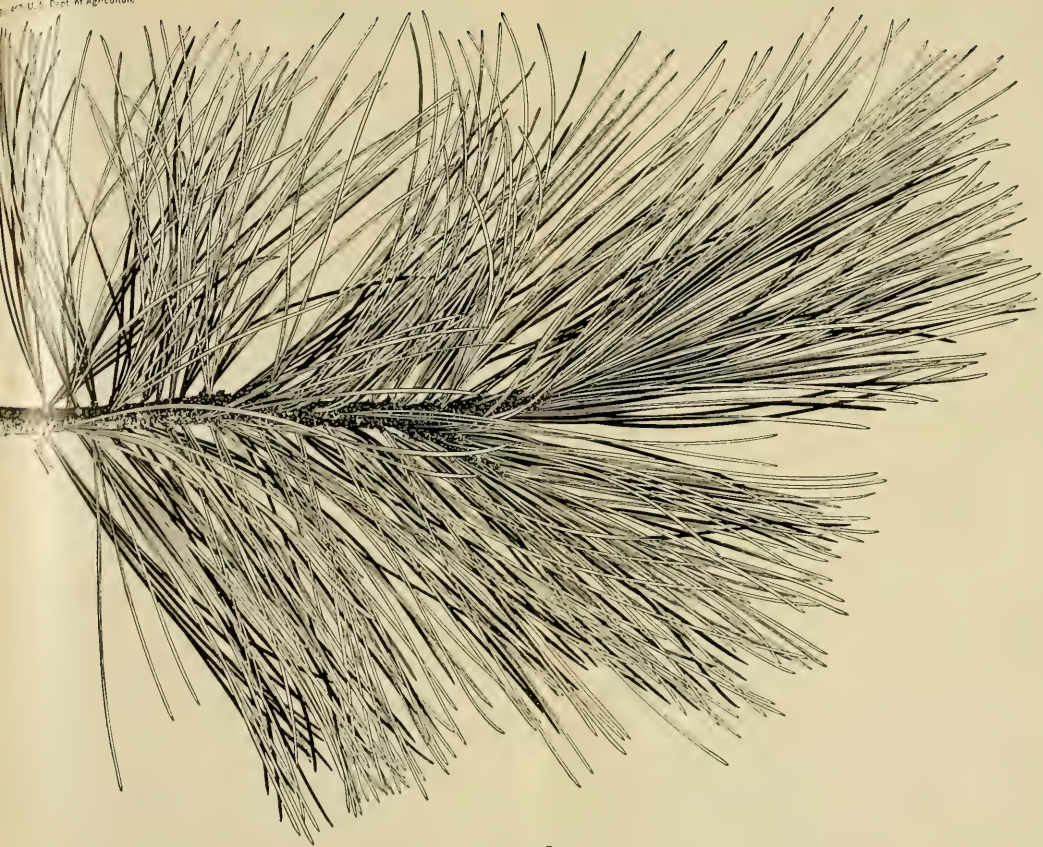
PINUS STROBIFORMIS: LARGE FORM OF OPEN CONE.

a, b, Different forms of cone scales (upper side); c, upper side of cone scale with its seed; d, seeds.

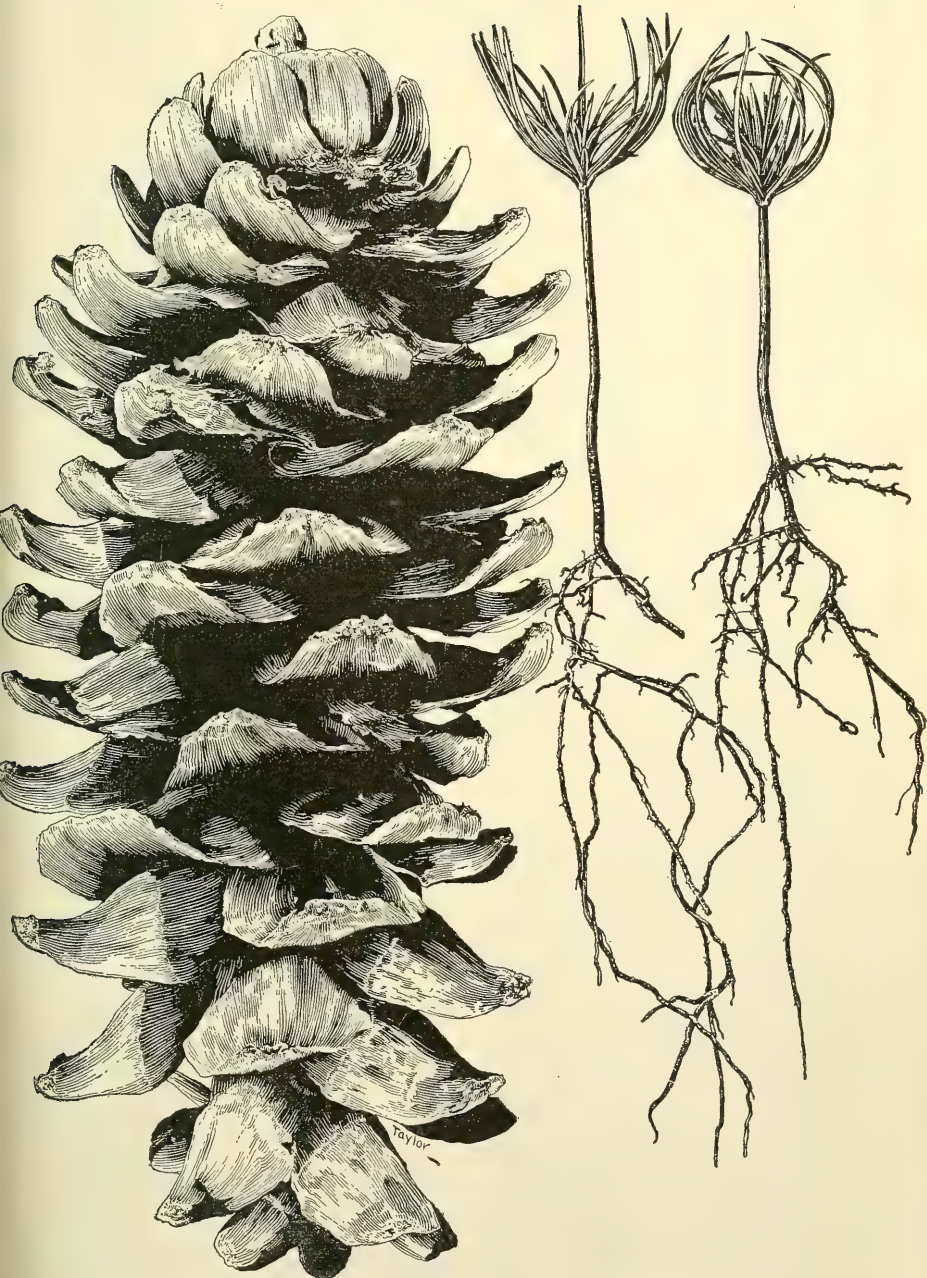


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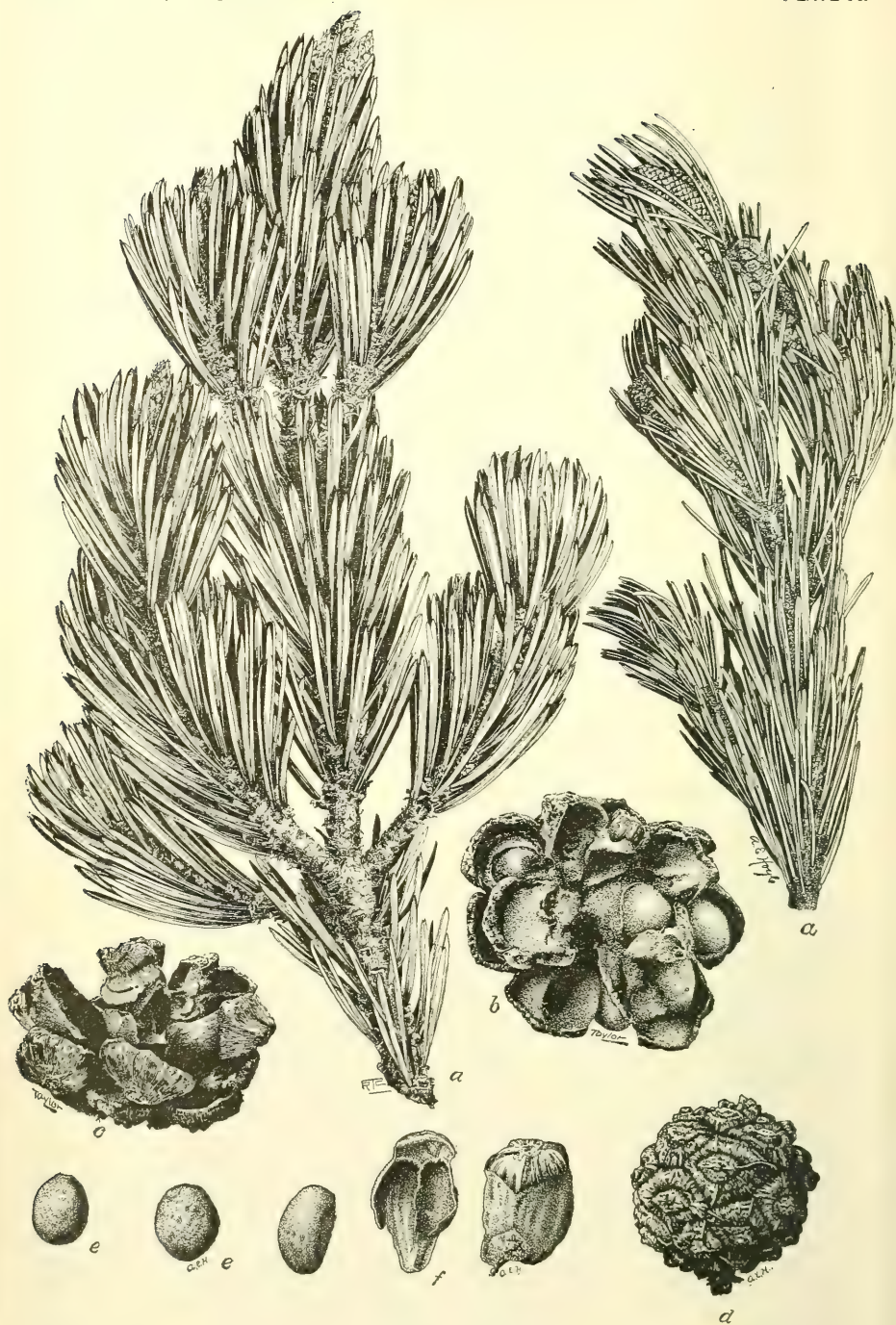




PINUS STROBIFORMIS: FOLIAGE.



PINUS STROBIFORMIS: OPEN CONE. (NATURAL SIZE.)
a, Seedlings about two months old (two-thirds natural size).



PINUS CEMBROIDES.

a, Foliage; b, top view of open cone with seeds; c, side view of open cone; d, ripe closed cone; e, seeds; f, cone scales, showing upper and lower sides.

maintain it as a species and to retain for it Engelmann's original name, *P. strobiformis*. While the cone scales of *P. ayacahuite* Ehrenberg and *P. ayacahuite veitchii* Shaw, wholly Mexican pines, resemble those of *P. strobiformis* Engelm., the seed wings of the first two pines are well defined and from two to three times as long as the seeds, while the seed wing of *P. strobiformis* is very rudimentary, being scarcely one-eighth of an inch long.¹

DISTINGUISHING CHARACTERISTICS.

The longer-leaved forms of this tree, grown in protected places at low elevations, have somewhat the aspect of the eastern white pine (*Pinus strobus*), while the shorter-leaved trees, found in exposed higher situations, have a general resemblance to the limber pine (*Pinus flexilis*). Mexican white pine usually has a narrow conical crown with drooping branches, especially the lower ones, and a rather short, clear, straight, often rapidly tapering trunk. In favorable situations, and when they have reached their full growth, the trees are from 60 to nearly 100 feet high and from 16 to 20 inches in diameter, or exceptionally from 28 to 36 inches in diameter. Commonly, however, the height is from 50 to 60 feet and the diameter from 14 to 16 inches. The trunk bark, about $1\frac{1}{4}$ inches thick, is dull red-brown and rather deeply and irregularly furrowed and narrowly ridged, the main ridges being more or less connected by smaller ones and composed of small, easily detached scales. The young twigs are at first covered with reddish-brown hairs, most of which disappear during the first winter.

The pale blue-green leaves (Pl. VIII), borne in clusters of five, are slender, rather stiff, and from 3 to about 4 inches long. Leaves of each season's growth remain on the twigs for about four years; some of them, however, are shed during the third year. Retention of each season's leaves until practically the fourth year gives the crown a dense, well-clothed appearance. The margins of the leaves have minute, sharp, widely separated teeth. A cross section of the leaf shows two resin ducts (on the back of the leaf near the border). The lower or ventral sides of the leaves are marked with from 3 to 4 lines of minute pores (stomata), none being found on the back or dorsal sides of the leaves. This characteristic, first pointed out by Coulter & Rose in 1886, may serve to separate perplexing forms of this pine from its close relative *Pinus flexilis*, the leaves of which have dorsal stomata.

¹ So far as is known *Pinus strobiformis* has not been introduced into cultivation in Europe, nor has it been cultivated in eastern United States. Judging from the behavior of *Pinus flexilis* in England, to which *Pinus strobiformis* is similar in its requirements of soil and climate, the Mexican white pine also is likely to be adapted for growth in that country. The poor showing made by *Pinus flexilis* in eastern United States similarly indicates that *Pinus strobiformis* would not grow well in that region.

Mature cones are from $4\frac{3}{4}$ to $9\frac{1}{4}$ inches long (Pls. VII and IX). The most distinctive characteristic of the cone is the strongly reflexed thin tips of the cone scales. (Pl. VII, *a*, *b*.) No other pine in the United States has cones so strongly marked. The pendent cones are mature about the middle of September and usually drop their seeds by the middle of October. They fall from the trees in late autumn or early winter. At maturity the cones are light yellowish-brown, unexposed parts of the scales being dull red. The nutlike seeds are dark brown, slightly tinged with red, and are provided with a very short wing. (Pl. VII, *c*, *d*.) The seed-leaves are from 10 to 12 in number. (Pl. IX, *a*.)

The wood of Mexican white pine is moderately heavy for a white pine, a cubic foot of it when dry weighing about $30\frac{1}{4}$ pounds. It is rather hard and narrow-ringed ("fine-grained"¹). The sapwood is thin and whitish, the heartwood being a very pale reddish-brown. In general appearance and texture lumber from this tree resembles that from old trees of the eastern white pine (*Pinus strobus*), while its "working" qualities are similar to those of western white pine (*Pinus monticola*). The limited distribution of this tree in the United States and its occurrence in places difficult of access has so far prevented any but local use of the timber, the best grades of which would readily serve as a substitute for western white pine.

OCCURRENCE AND HABITS.

Mexican white pine grows in dry, rocky, or gravelly soils on mountain slopes, canyon sides, and ridges at elevations of from about 5,500 to 9,700 feet; it is only very occasionally that straggling trees

¹ The popular conception of the "grain" of wood appears to refer mainly, if not entirely, to the thickness of the annual layers of growth. Thus woods with thin or thick layers of growth are commonly called "fine-grained" or "coarse-grained." Such other qualities of wood as compactness or density and porosity of structure are popularly described as "dense," "very dense," "compact," or as "porous" and "nonporous." In view of this evident popular confusion in reference to "grain," it is here maintained that grain should properly refer only to the structural constitution of wood within the annual or other periodic layers of growth, and not to the thickness of the annual increment, which is consistently described by such terms as "wide-ringed" and "narrow-ringed" wood. Uniform thickness of the periodic layer of growth is only exceptionally characteristic of any wood under all conditions of the tree's life, while the structural elements of different woods remain fairly constant. The characteristic structure of different woods results from the association of different individual cell-elements (fibers and vessels). These elements have distinctive forms, which vary within limits characteristic of different groups of woods, and also of the same species grown under different conditions. Wood elements are also characteristically assembled in different genera and species of woods. In one, these elements may be so associated as to form the popular and correctly termed "cross-grained" wood, as in sycamore (*Platanus*) and in gum (*Nyssa*), etc. In another, they may form "straight-grained" wood, as in white ash, white pine, etc. Again, the elements may take a wavy longitudinal course, or an abruptly-curved course, and produce the "curly-grained" and "bird's-eye" wood. So also, when the elements are spirally disposed with reference to the axis of the tree, the wood has a "twisted grain." If all of the elements of a wood are small and about the same width, the structure can properly be termed "fine-grained." So, too, if many of the cell-elements are large, the wood produced is "coarse-grained."

are found at as low a level as 5,500 feet (Map No. 4). The largest and best-formed trees are found on moist, gravelly flats and canyon slopes at elevations between 7,000 and 8,000 feet. They are commonly much scattered, growing singly or occasionally in small groups, and generally associated with Arizona pine and Douglas fir at higher elevations.

This pine can endure moderate shade only during the seedling and small sapling stages of growth. After this it requires full overhead light. Older overtopped trees show greatly reduced vigor in the density of foliage and also in the rapidity of their height and diameter growth.

Mexican white pine is a moderate seeder, the amount of seed borne varying with the elevation. Seed production is greatest at the middle elevation, even the better grown trees in protected places at lower altitudes producing smaller quantities of seed. Good crops of seed are borne at intervals of about 3 years, although some seed is produced nearly every year. The nutlike practically wingless seeds fall near the trees and soon afterwards many of them are devoured by birds and squirrels. The latter also eat the seeds of a large number of the ripe closed cones, which they "cut down." This destruction of perhaps the major part of the season's crop doubtless accounts for the sparse reproduction of the species. Germination occurs most often in mineral soil held in pockets or otherwise protected from washing. In some instances mountain flood waters carry the seeds to lower levels than they would ordinarily reach, thus extending the vertical distribution of the tree to exceptionally low elevations (5,500 to 6,000 feet).

LONGEVITY.

Pinus strobiformis is a moderately long-lived tree and of fairly rapid growth. Trees from 14 to 20 inches in diameter are approximately from 80 to 110 years old, and those from 28 to 30 inches through are from 150 to 180 years old. It is probable that this pine reaches an age of 250 years or more in protected situations. Further determinations are required to fix the extreme limit of age.

MEXICAN PIÑON.

Pinus cembroides Zuccarini.

COMMON NAME AND EARLY HISTORY.

Of all of our nut pines this species is perhaps the least known to laymen. It has no distinctive common name, being called "piñon" and "nut pine." The name Mexican piñon, here used to distinguish the tree from other nut pines, would appear to be appropriate, because the species occurs almost wholly in Mexico (Map No. 5).

Pinus cembroides was discovered¹ about 1830 by the Belgian explorer Karwinsky in the southern part of the State of Mexico.² It remained unknown in the United States until 1882, when it was found on the Santa Catalina Mountains, Arizona, by Mr. C. G. Pringle,³ an American botanist and explorer. *Pinus cembroides*, the first technical name applied to the Mexican piñon, was published in 1832.⁴

DISTINGUISHING CHARACTERISTICS.

Mexican piñon is ordinarily a very short-trunked tree from 12 to 25 feet high and from 7 to 12 inches in diameter. Such trees have a clear trunk of from 3 to 8 feet. Trees growing in protected places reach a height of from 35 to 50 or more feet, with 15 to 18 feet of clear trunk and a diameter of from 12 to 14 inches. The crowns of young trees are compact and conical, the branches being more or less upright; the crowns of old trees are wide and rounded, the lateral crown branches being mostly horizontal. On large trunks the bark is pale reddish brown, distinctly scaly, thin (not over half of an inch thick), and divided by very shallow furrows and ridges, which are not connected by smaller side ridges as in the case of other nut pines.

The foliage, especially on young trees, is a deep bluish green, that of each season's growth remaining on the branches about 4 years, though most of it falls during the third or fourth season. The number of leaves borne in a bundle is commonly 2 or 3 (rarely and exceptionally 1, 4, and 5). They are from about 1 to 2 inches long, acutely pointed, strongly incurved, and smooth on the margins. A

¹ Fide Sargent, *Silva*, XI, 48. 1897.

² According to Elwes and Henry (*The Trees of Great Britain and Ireland*, V. 1059, 1910) *Pinus cembroides* was introduced into England in 1830. (If this date be correct, it is probable that Karwinsky, the discoverer of the tree, found it in Mexico at an earlier date than "about 1830," the year indicated by Prof. Sargent, l. c.). They state that in 1908 trees of this species planted in England reached a height of 25 to 33 feet. It is said to have been introduced into Europe by Hartweg in 1846 (fide Sargent, l. c.) and is now cultivated for ornament in southern Europe.

³ Sargent, l. c.

⁴ Since the first publication of this tree as a species in 1832 botanists have generally held it to be distinct from the other southwestern nut pines, the only names applied to it, until quite recently, being *P. haveana* Schl. and *P. osteoperma* Engelm., now relegated to synonymy. In 1907, however, a German botanist (Voss, *Mitt. Deutsch. Dend. Presell.*, XVI, 95, 1907) pronounced it to be related to the single-leaf pine and the two-leaf piñon, which he designates as *P. cembroides* var. *monophylla* and *P. cembroides* var. *edulis*, to which he has also added our southern California four-leaf pine (*P. parryana*) as *P. cembroides* var. *parryana*. This writer considers the cones of all of these piñons essentially alike; and, owing also to the inconstancy in the number of leaves borne by each, he is unable to separate them satisfactorily as species. The present writer, however, prefers to maintain the Mexican piñon as a distinct species: (1) because, in the main, our forms of the tree have a reasonably constant number of leaves in each fascicle; (2) because the cones are distinguishable in size and other characteristics, the seeds also having the same general distinctions; (3) because the bark is distinctly scaly and only slightly ridged, that of the other nut pines being markedly ridged; (4) because the number of seed-leaves is greater than in any other nut pine; (5) and, lastly, because the wood has characteristics which distinguish it.

cross section of the leaf shows two resin ducts (near the border on the back of leaf).

The cones ripen during September and drop their seeds¹ by the middle or latter part of October. Only the scales in the middle of the cones bear perfect seeds. Externally, the cones are pale yellowish or reddish brown. The empty cones fall from the trees mostly in late autumn and early winter. Mature cones (Pl. X, *b*, *c*) which are globelike or egg-shaped and borne on very short stems, vary in length from about 1 inch to $2\frac{1}{2}$ inches, and in breadth from about 1 inch to nearly $2\frac{3}{4}$ inches. The seeds (Pl. X, *e*) are from one-half to three-fourths of an inch long by about one-fourth to three-eighths of an inch wide. They vary in color from light yellowish brown to a deep chocolate-brown on the under surface (which is always darker) to cinnamon-brown on the upper side. The pale cinnamon brown wings of the seeds are extremely short (rudimentary) and remain attached to the scales when the seeds fall (Pl. X, *b*, *c*, *f*). Seed-leaves are from 9 (occasionally 8) to 15 in number.

The wood of *Pinus cembroides* is very narrow-ringed, and moderately soft, but firm. It is the heaviest of all the Rocky Mountain pines, a cubic foot of dry wood weighing about $40\frac{1}{2}$ pounds. In this country the wood is used locally only for fuel and for other minor domestic purposes.

OCCURRENCE AND HABITS.

Pinus cembroides grows in poor, shallow, rocky, and gravelly soils on hot mountain slopes, precipitous canyon sides, benches, and foothills at elevations between 4,800 and 7,500 feet (map No. 5). Within our border it forms scattered growths, interspersed here and there with *Quercus reticulata*, *Q. hypoleuca*, and *Q. arizonica*. In its more extensive range in Mexico it sometimes occurs in practically pure, but rather open stands.

The light requirements of this species are insufficiently known at present; but it appears to be intolerant of shade, except during early youth, and even at that time it endures only partial shade.

Seed production occurs usually every other year, but heavy crops of seed are borne only at intervals of three or four years. Trees begin to bear cones comparatively early, seed production increasing steadily to old age. A large percentage of the seeds are sound, but their vitality is very transient, so that, except under specially favorable conditions for germination, reproduction occurs sparingly. Seedlings are generally much scattered, and mainly on washed mineral soil. Sparse reproduction where the tree occurs abundantly is prob-

¹ The seeds are extensively gathered for food in Mexico; but in the United States few are obtained for this purpose because of the limited occurrence of the tree.

ably due, in large measure, to the fact that quantities of the seed are collected for food and for sale as sweetmeats, while in localities where this pine is less abundant rodents and birds devour much of every crop, for shortly after the seeds have fallen it is often difficult to find a single perfect one.

LONGEVITY.

The extreme age limit of Mexican piñon has not been determined. It grows very slowly throughout its life, attaining an age of possibly 225 years. Trees from 7 to 10 inches in diameter are from 125 to 185 years old.

PIÑON; NUT PINE.

Pinus edulis Engelm.

COMMON NAME AND EARLY HISTORY.

This distinctly desert-foothill tree is rarely if ever distinguished by lay people from the single-leaf pine (*Pinus monophylla*), especially where the two species are mingled. Sometimes the long-leaved and larger-coned forms of *Pinus monophylla* and the shorter-leaved, smaller-coned forms of *P. edulis* are spoken of as different "varieties" of the piñon tree that yields the "pine nuts" which Indians and settlers gather for food.

The history of the piñon is closely connected with that of the single-leaf pine and shows that there has been much difference of judgment, which obtains even at the present time, regarding their botanical relationship, particularly their claims to specific rank. Single-leaf pine was found for the first time by Gen. John Charles Frémont in 1844 in southern California and was described in 1845 as a distinct species under the technical name *Pinus monophylla* Torrey. Similarly, the piñon, found first by Dr. Wislizenus in New Mexico in 1846, was botanically described in 1848 for the first time as a distinct species under the name *Pinus edulis* Engelm.¹ Forty-three years after this (1891) the latter tree was reduced to a variety of the single-leaf pine and designated as *P. monophylla* var. *edulis* M. E. Jones, while 16 years later (1907) it was again described as *P. cembroides* var. *edulis* Voss.² Writers have differed also as to the proper botanical rank of the single-leaf pine; for in 1860, 15

¹ It is not definitely known when *Pinus edulis* was first cultivated in England or in European gardens, where it is said to be growing. Elwes and Henry (Trees of Great Britain and Ireland, V, 1058, 1910) state that small plants of it are growing in Kew Gardens. Prof. Sargent (Silva, XI, 57, 1897), says that it is hardy in eastern United States as far north as eastern Massachusetts. In 1886 the writer saw a small tree of this species, planted by William Saunders in the grounds of the Department of Agriculture about 1870. It died in 1888 after reaching a height of about 5 feet, apparently not being adapted to the soil and climatic conditions at Washington, where its growth had been exceedingly slow.

² See footnote 4, page 16.

years after it was first described as a distinct species (*P. monophylla* Torrey), it was reduced to the rank of a variety (*P. edulis* var. *monophylla* Torrey); and 47 years later (1907) it, too, was designated as *P. cembroides* var. *monophylla* Voss,¹ a judgment in which at least one author has concurred as late as 1909.

The present writer prefers, however, to consider the piñon and single-leaf pine as distinct species. For this opinion there is good ground in the microscopic structure and external form of the leaves of both trees, as well as in the size of their cones. Perplexing and anomalous leaf forms of both trees occur, particularly where the ranges of the two trees come together. Thus it is possible to find individual trees in southern Utah bearing one-leaved and two-leaved fascicles, but these must be considered *P. edulis*, because the apparently monophyllous fascicles can usually be shown to be structurally two-leaved. So also anomalous two-leaved fascicles of trees bearing mostly single leaves will generally have the essential anatomical structure of *P. monophylla*, to which such exceptional trees must be referred.² It should be noted in this connection that similar variations from the usual number of leaves borne are peculiar also to other western and eastern pines. In the case of these species, however, such variations have not yet been considered sufficient ground for uniting them as varieties.

DISTINGUISHING CHARACTERISTICS.

The piñon has a short, often crooked, trunk, which gives off several large, crooked branches and is rarely clear of limbs for more than 15 feet, and usually for only 6 or 8 feet. Young trees have broad cone-shaped crowns, but when the trees have become full grown the crown is spherical or occasionally somewhat flat-topped. The height attained varies from 10 to 35 feet or more, but commonly it is from 12 to 16 feet, with a diameter of from 12 to 30 inches. The irregularly developed, leaning, crooked trunks and low-hanging branches of this pine give it the general appearance of an old apple tree. The bark of mature trunks is shallowly and irregularly furrowed, the main ridges being joined by diagonally disposed smaller ridges. Both the main ridges and the smaller ones are broken into small, close, detachable scales. Superficially the bark has a tint of yellowish or reddish brown. It varies in thickness from about one-half to seven-eighths of an inch.

¹ See footnote 4, page 16.

² How far we have in the anomalous forms of these two piñons evidences of the derivation of a one-leaved species from the probably more ancient two-leaved tree it is impossible to say at present. The somewhat more arid habitat, in part, of the one-leaved tree would seem to support belief that the one-leaf form of foliage is the direct result of a physiological necessity—a leaf of such simple character as would permit the tree more easily to maintain itself under arid conditions.

The foliage of adult trees is a dark yellowish green, while that of seedlings is a bright bluish green. Each season's growth of leaves remains on the branches for nearly 9 years, though a good many leaves fall during the fourth summer. The leaves are borne in clusters of 2, occasionally of 3 (Pls. XI, XII). They are sharp pointed, often curved, and vary in length from about seven-eighths of an inch to nearly $1\frac{3}{4}$ inches. The margins of the leaves are smooth (without minute teeth). In cross section the leaves show two resin ducts.

The yellowish-brown and somewhat shiny cones (Pl. XI) are from about $1\frac{1}{4}$ to nearly $1\frac{3}{4}$ inches long. They ripen in August and September and shed their nutlike edible seeds (Pl. XI, *b*) during the latter part of September and in October, the very short rudimentary wings (from one-eighth to one-sixth of an inch long) remaining attached to the cone scales (Pl. XI, *a*) when the seeds fall. Unexposed parts of the cone scales are pale red-brown. The perfect seeds,¹ borne only by scales in the middle of the cone, are pale yellow with reddish-brown specks and mottlings on one side and dull red-brown on the other. Most of the empty cones fall from the trees during the first winter or early the following spring. The seed-leaves (Pl. XII, *a, b*) vary in number from 7 to 10.

The wood of *Pinus edulis* is narrow-ringed and hard, but very brittle. The thin layer of sapwood is nearly white, and the heartwood is light yellowish brown. Next to that of *Pinus cembroides* it is the heaviest of Rocky Mountain pine woods, a cubic foot of dry wood weighing nearly 40 pounds. It is used largely for fuel, ties, fence posts, and other local purposes.

OCCURRENCE AND HABITS.

Pinus edulis grows on dry foothills, mesas, mountain slopes, and sides of canyons, at elevations between 5,000 and 9,000 feet, or occasionally somewhat below 5,000 feet (Map No. 6). It is usually found in poor, rocky, gravelly soils, but often in shallow or deep layers of gravel and sand overlying rock, and sometimes in the crevices of rocks. Very commonly, it is associated with western yellow pine, one-seed juniper, Utah juniper, mountain mahoganies, Gambel oak, and mountain red cedar. Its most frequent associates are, however, the one-seed and Utah junipers. Occasionally it forms pure stands of limited extent. The largest growths occur on mesas and elsewhere at the lower elevations noted, where the sandy or gravelly soil deposited by washing is moderately rich.

Piñon is very intolerant of shade in all but the seedling stages of its growth, a period when partial shade assists the young plants to

¹ Indians and settlers gather large quantities of the seeds; the former use them largely for food, and the latter send them to eastern and other city markets as sweetmeats. Birds and squirrels and other rodents, however, claim a large share of piñon seeds, many of which are devoured before the cones open.



PINUS EDULIS: FOLIAGE AND OPEN CONES.

a, Upper and lower sides of cone scales; b, seeds.



PINUS EDULIS: FOLIAGE.

a, Seedlings one month old (natural size); *b*, seedlings six months old (one-third natural size).



PINUS MONOPHYLLA: FOLIAGE.

a, b, Open cones; c, upper side of cone scale with its seeds.



PINUS MONOPHYLLA: FOLIAGE AND OPEN CONE (ATTACHED TOP VIEW).
a, Detached closed cone.

become better established than in the full sunlight. Piñon bears seed very abundantly about every 2 years, but sometimes only at intervals of 3 years. The wingless nutlike seeds always fall beneath or near the trees. When fruiting trees occur on slopes, the seeds may be washed some distance away and sometimes into depressions and crevices where, when buried in soil or débris, they have the most favorable opportunity for germination. Very few seeds that are left on top of the ground germinate. As a rule, therefore, reproduction is very sparse and much scattered, never dense. Scanty reproduction is, however, doubtless due also to the fact that so large a part of each seed crop is devoured by birds or mammals and gathered by settlers and Indians.

LONGEVITY.

Piñon is a very slow-growing tree, attaining an age of from 150 to 375 years or more.

SINGLE-LEAF PINE.

Pinus monophylla Torrey and Frémont.

COMMON NAME AND EARLY HISTORY.

This species is unique among all North American pines in having single leaves. Generally it is known only as "nut pine" or "piñon." It is desirable, therefore, in order popularly to distinguish this tree from other nut pines, to adopt "single-leaf pine" as its common name.

Pinus monophylla was discovered in 1844 in Cajon Pass, San Bernardino County, southwestern California, by Gen. John C. Frémont, while on his expedition through Oregon and California.¹ The first technical name applied to it, *Pinus monophylla* Torrey, was published in 1845. Two years later (1847) the German botanist Endlicher described and named it "*Pinus fremontiana*," and in 1860 Dr. Torrey designated it as *Pinus edulis* var. *monophylla*. The last name applied to it is *Pinus cembroides* var. *monophylla* Voss.²

DISTINGUISHING CHARACTERISTICS.

Single-leaf pine is characteristically a low, sprawling tree. Mature trees have short trunks, which are rarely straight, and wide, rather

¹ *Pinus monophylla* was introduced into cultivation in Europe in 1848, where, according to Elwes and Henry (The Trees of Great Britain and Ireland, V, 1057, 1910) some specimens of it appear to have grown very slowly, although a few trees have grown more rapidly and are healthy. The largest trees found by Elwes and Henry (l. c.) were from 13 to 20 feet high between 1908 and 1910. Single-leaf pine is occasionally cultivated in eastern United States, where it is hardy as far north as eastern Massachusetts (Sargent, Silva, XI, 53, 1897). Its growth there is, however, exceedingly slow. Like the piñon, this pine is not attractive for ornamental planting.

² See footnote 4, page 16.

flat crowns of short, heavy, twisted, and bent branches. The latter grow from near the ground and often hang low, giving the appearance of an old apple tree. Young trees are very different in appearance because their low, thick trunks, have pyramidal crowns of rather straight, ascending branches. As a rule, the single-leaf pine does not exceed 25 feet in height and from 12 to 15 inches in diameter. In protected and otherwise favorable situations it may, however, reach a height of from 35 to 50 feet. The bark of young trees is smooth and dull gray, while that of old trees is roughly and irregularly furrowed, nearly an inch thick, and with thin, close, dark brown, or sometimes reddish brown scales. The general color of the foliage is pale yellow green, with a whitish tinge. The single (or very occasionally double) leaves are stiff, curved toward the branch, prickly, and from about $1\frac{1}{3}$ to $2\frac{1}{4}$ inches long; generally they are about $1\frac{1}{2}$ inches long (Pls. XIII, XIV). Each season's growth of leaves remains on the tree about 5 years: not infrequently, though, leaves persist for 10 or 12 years. A striking peculiarity of seedling trees is that they continue to produce only primary leaves for 6 or 7 years, after which they put forth the adult form of foliage.

The cones (Pls. XIII, *a*, *b*, and XIV, *a*) are matured in August of the second season, and the tips of the scales are then shiny and a deep russet-brown. The seeds fall within about a month afterwards. Most of the empty cones (Pl. XIV) fall from the trees during the winter or spring. The seeds (Pl. XIII, *c*) are dark chocolate-brown with dull yellowish areas. The pale brown seed wings, ragged and irregular, are from one-fourth to one-half of an inch long and remain attached to the cone scales (Pl. XIII, *c*—the torn border at inner ends of seeds). Seed-leaves of this pine range from 7 to 10 in number.

The wood of single-leaf pine is very narrow-ringed, exceedingly brittle, and rather soft. It usually has a thick layer of whitish sapwood, the heartwood being a pale yellowish brown. A cubic foot of dry wood weighs about $35\frac{1}{4}$ pounds. Settlers use large quantities of the wood for fuel and temporary fence posts, and a good many small towns within reach of the timber derive their principal supply of fuel from it.

OCCURRENCE AND HABITS.

Single-leaf pine occurs on low arid mountain slopes, canyon sides, foothills, and mesas, commonly at elevations between 2,000 and 7,000 feet, or less frequently up to 9,000 feet (map No. 7). Its requirements of soil moisture and quality of soil are closely similar to those of its frequent associates, the junipers, piñon, and chaparral, but less

than in the case of other conifers in its general range. Single-leaf pine occurs commonly in coarse, gravelly soils, shallow deposits overlying granite, limestone, or shale and often in the crevices of rocks. It frequently forms pure, open stands over large areas, but usually it is associated with other trees, such as mountain mahogany, Utah juniper, mountain red cedar, oaks, tree yuccas, and occasionally with piñon. The largest trees and the pure stands occur mainly at the lower and middle levels of the tree's vertical range.

Pinus monophylla is very intolerant of shade throughout life. Seedlings grow faster, however, for several years under partial or light shade and also when protected from hot winds.

This species bears some seed nearly every year and abundantly at intervals of two or three years. As in the case of other nut pines, the wingless seeds fall near the tree, whence they are sometimes disseminated by flood waters. Birds and squirrels eat large quantities of them and Indians and whites collect them extensively for food. Exposed loose soil is the best seed bed, though even here germination occurs sparingly, so that reproduction is very scattered.

LONGEVITY.

Pinus monophylla is an exceedingly slow growing tree, reaching an age of from 100 to 225 years. Trees in thin, dry soil are especially slow in their growth, specimens from 4 to 6 inches in diameter being from 80 to 100 years old. Trees occurring in deeper soils grow more rapidly, those from 10 to 12 inches in diameter being from 150 to 160 years old. Further records are required to establish its extreme age limit.

BRISTLE-CONE PINE.

Pinus aristata Engelm.

COMMON NAME AND EARLY HISTORY.

Bristle-cone pine is known to people in and near its high mountain habitat chiefly as "fox-tail pine," because of the close resemblance of its foliage to that of the true fox-tail pine (*Pinus balfouriana*), a California species. It is sometimes known also as "hickory pine." An appropriate and distinctive name is bristle-cone pine, which is derived from the tree's specific name, *aristata* (bearded), referring to the bristlelike prickles of the cone scales.

It is probable that the earliest discovery of this pine was made in 1853 by Capt. J. W. Gunnison, of the U. S. Army, who collected a coneless branch in Cochetopa Pass (nearly southwest of Pikes Peak), Colorado, which Dr. Engelm¹ believed to be of this

¹Trans. St. Louis Acad. Sci., II, 205. 1863.

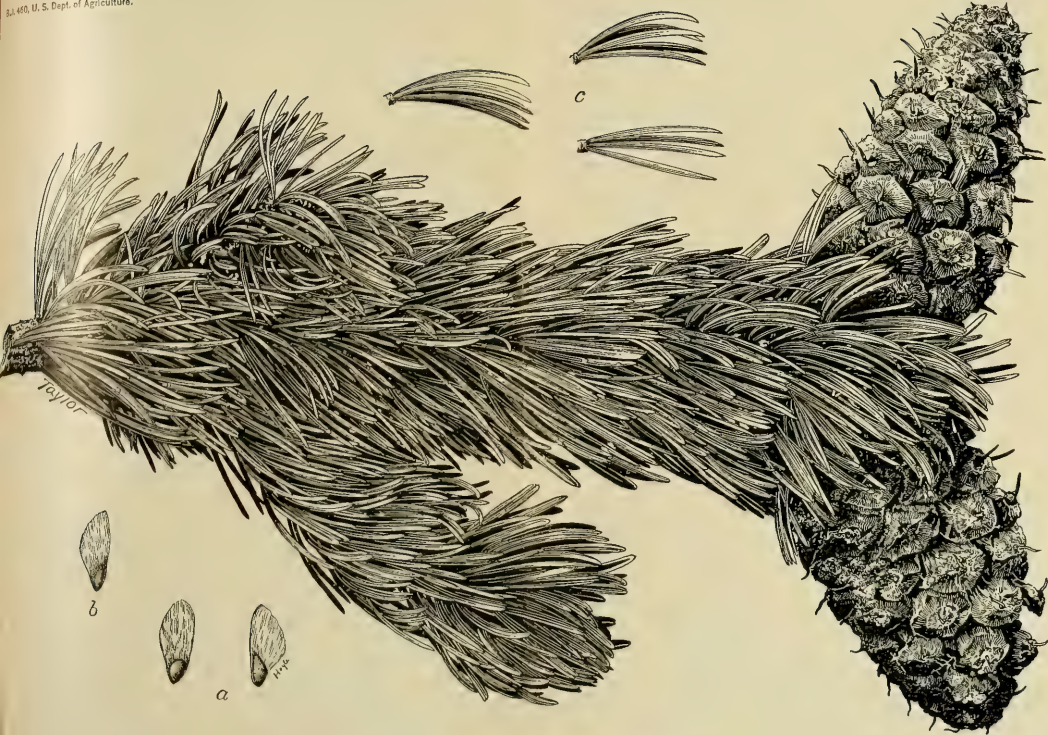
species. So keen an observer as Dr. Engelmann could hardly have mistaken the foliage of any other Rocky Mountain pine for that of *Pinus aristata*. The first authentic specimens of the tree were, however, collected by Dr. C. C. Parry on Pikes Peak, Colorado, in 1861. Bristle-cone pine received its present technical name, *Pinus aristata*, in 1862, since which date the history of the tree has been practically free from confusion. In 1878 it was designated as *P. balfouriana* var. *aristata* Engelm., but this suggested relationship to the California species is not generally accepted.²

DISTINGUISHING CHARACTERISTICS.

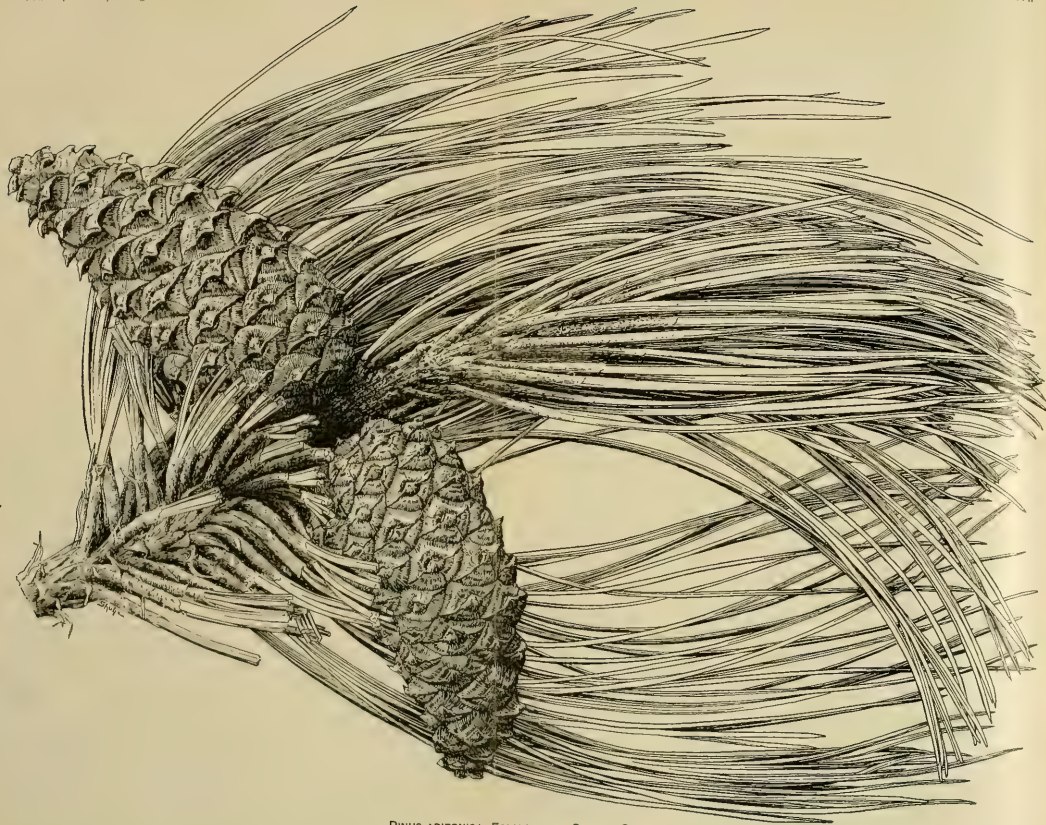
Bristle-cone pine varies in height and form from a half-prostrate twisted shrub, at very high elevations, to a bushy-crowned tree from 35 to 40 feet, in the situations more favorable for growth. Ordinarily it is from 15 to 30 feet high and from 12 to 18 inches in diameter, the tallest trees being from 20 to 30 inches or more in diameter. The trunk is clear of branches for about 6 or 8 feet. The rather wide bushy crown of long, drooping lower branches and of irregularly long upright top limbs is characteristic of single trees or those in open stands on wind-swept slopes. In denser stands, in less exposed situations, the crown form is narrower. Young trees have a distinctly pyramidal crown with short rather thick branches which stand out from the stem at right angles. The bark of old trunks is a dull reddish brown and rather shallowly furrowed, the main flat ridges being irregularly connected by narrower diagonal ones. Bark on the trunks of small trees and of the large limbs of old trees is smooth and chalky white.

The deep green foliage is densely clustered at the ends of the branches, the needles being closely pressed down (Pl. XV), in this respect closely resembling the true fox-tail pine (*Pinus balfouriana*). As a rule, the leaves are borne in clusters of 5, occasionally of 4, and are about $1\frac{1}{4}$ to $1\frac{1}{3}$ inches long (Pl. XV, c). The leaves of each season's growth persist for approximately 12 or 14 years.

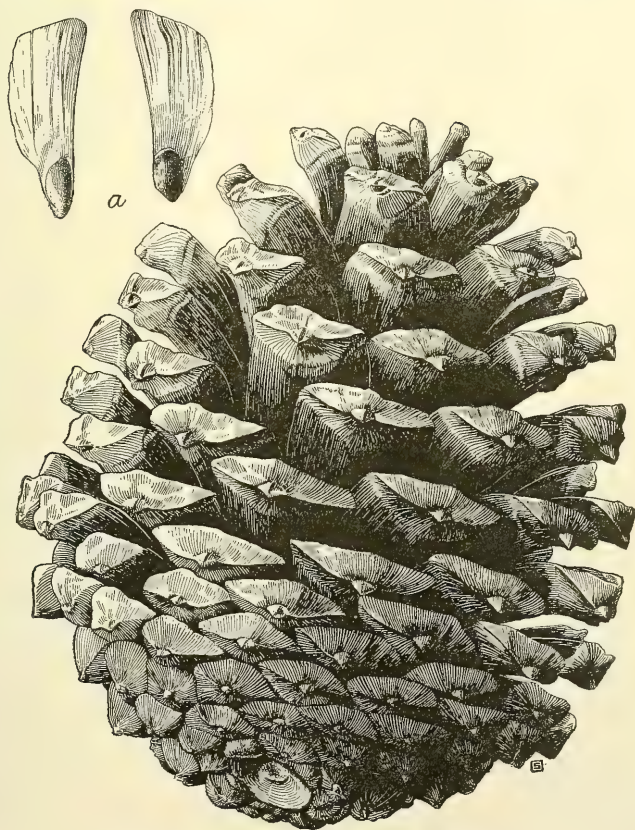
¹ *Pinus aristata* was first introduced into cultivation at the Harvard Botanic Garden, by Dr. Asa Gray, to whom Dr. Parry sent seeds from Colorado in 1862. Dr. Gray raised a number of seedlings from this seed, and Prof. C. S. Sargent (Gard. and Forest, X, 470, 1897) states that some of these plants still growing in the vicinity of Boston had in 35 years attained heights only of from 12 to 18 inches, from which it would seem that the species is not adapted to that part of our Atlantic region, and certainly not to regions farther south. A trial of this pine near Portland, Me., shows decidedly better results. Mr. H. A. Jackson writes that trees he raised from seed planted in 1908 are now (1917) $2\frac{1}{2}$ feet high and growing thriftily. Accounts differ as to when this pine was first introduced into England, the date given in one instance (Gard. Chron. IV, 549, 1875) being 1863, and in another (Gordon, Pinetum, ed. 2, 292, 1875), 1870. It appears to be better adapted to the climate of England, where, according to Elwes and Henry (The Trees of Great Britain and Ireland, V, 1055, 1910) trees have attained heights ranging from 15 to 25 feet during a period, probably, of 35 to 40 years.



PINUS ARISTATA: FOLIAGE AND OPEN CONES; SEEDS WITH WINGS.
a, Upper side; b, lower side; c, detached leaf bundles, showing different lengths.



PINUS ARIZONICA: FOLIAGE AND CLOSED CONES.



PINUS ARIZONICA: DETACHED OPEN CONE.

a, Upper (right) and lower sides of seeds and wings.

The cones mature at the end of the second season, and are then from $2\frac{1}{2}$ to about $3\frac{1}{2}$ inches long and of a deep chocolate-brown color tinged with purple. Each cone scale bears a bristlelike, very fragile prickle, which easily distinguishes the cones of this pine from other species of the region. Unexposed parts of the cone scales are clear reddish brown. The seeds (Pl. XV, *a*, *b*) are pale brown with irregular black spots, and are shed from about the last of September to the middle of October. Seed-leaves of this pine vary in number from 6 to 7.

Bristle-cone pine produces rather narrow-ringed, soft, brittle wood with a thin layer of whitish sapwood and a pale brownish-red heart. It is moderately heavy for a white pine, a cubic foot of dry wood weighing about $34\frac{3}{4}$ pounds. On account of the poor timber form of the tree the wood is not used commercially. In the region of greatest abundance it is sometimes employed for fuel and mine props.

OCCURRENCE AND HABITS.

Pinus aristata is found on ridges and rocky ledges, but mainly on south slopes, here often predominating at elevations between 7,500 to 10,800 feet (Map No. 8). It grows on thin, rocky soil, and frequently on volcanic soils of cinder cones. Usually growths of this tree are in isolated situations, where snow melts early and evaporation is rapid, so that the trees are subjected to more or less prolonged dryness of soil during summer. Rarely does this species form pure stands, the trees being usually scattered over grassy ground of a gravelly or rocky nature with little or no underbrush. It is most abundant at higher levels, where limber pine is its only associate. At lower altitudes it is often associated with Engelmann spruce, limber pine, and western yellow pine, and occasionally with white fir.

Bristle-cone pine never forms dense stands, which indicates that it is intolerant of shade during the greater part of its life. Seedlings, however, endure light shade for several years without material loss of vigor.

Trees begin to bear cones when they are about 20 years old, and produce them practically every year thereafter, with specially heavy crops at intervals of several years. Reproduction is always sparse and much scattered. Seeding often takes place at a distance of at least 600 feet away from mother trees. The large number of seeds eaten by rodents and the ease with which surface fires destroy the large-winged seeds and kill the seedlings and dense-foliaged older plants doubtless account in great measure for the thin stands of this pine. Seeds germinate best in loose, exposed mineral soil, and less promptly in grass and litter. The seedlings appear to grow best on slopes with little or no underbrush.

LONGEVITY.

Little is known of the extreme age attained by this species. It is believed, however, to be moderately long-lived. Trees from 16 to 20 inches in diameter are from 200 to 250 years old.

YELLOW PINES.

Trees with rather hard, heavy wood in which the early- and late-formed portions of the annual layers are sharply defined.

ARIZONA PINE.

Pinus arizonica Engelm.

COMMON NAME AND EARLY HISTORY.

Arizona pine is little, if at all, known to laymen, who usually mistake it for the western yellow pine (*Pinus ponderosa*). This is probably because of its close general resemblance to the latter tree, with which it is more or less associated but from which it is roughly distinguished by the greater number of leaves it bears in each cluster or fascicle.

The specific technical name of this pine, *arizonica*, suggested because the tree was discovered in Arizona, is unfortunate, for the greater part of the range lies in Mexico. Similarly, the common name "Arizona pine," derived from the technical name, is inappropriate, but it is the only distinctive one available.

Dr. John T. Rothrock, prominent in recent years in Pennsylvania forest work, discovered this tree in 1874 on the Santa Rita Mountains, southeastern Arizona. Dr. Rothrock was then serving as botanist and surgeon to an expedition under Lieut. Wheeler, who was making a geographic survey of our Southwest. The tree was technically described and given its present name, *Pinus arizonica*, in 1878. Since then no other technical names have been applied to it, and its claim as a distinct species was not questioned until 1909, when Dr. G. W. Shaw,¹ believing it to be a variety of *Pinus ponderosa*, gave it the technical name of *P. ponderosa* var. *arizonica*. The fairly constant occurrence, however, of 5 leaves in a bundle and appreciably distinct characteristics of the cones appear to be good reasons for still maintaining Arizona pine as a species.

DISTINGUISHING CHARACTERISTICS.

Arizona pine attains a height of from 75 to 90 feet, or occasionally 100 feet, with a diameter of from 30 to 50 inches. The trunks are

¹ Pines of Mexico, 24, 1909.

straight and, in mature trees, free from branches for from one-third to one-half their height. The crown form of old trees is rounded, and that of young trees broadly conical. On old trunks the bark is about 2 inches thick, very dark or blackish brown, the close, separable scales often showing light reddish brown in the deep, narrow furrows and also when freshly broken.

Each season's growth of the dark yellow-green foliage remains on the branches about two years, beginning to fall during the third season. The sharp-pointed leaves (Pl. XVI), which are borne in clusters mainly of 5 (occasionally of 2-, 3-, and 4-, with the 5-leaved clusters), are from about 4 to sometimes $9\frac{1}{4}$ inches long, but commonly from 5 to 7 inches long. The leaves produced each year vary greatly in length, even on the same tree, according to whether the season is favorable or unfavorable for growth. The leaves have close, persistent, basal sheaths from three-fourths of an inch to 1 inch long. The sheaths are a pale yellow-brown at first, later becoming grayish with exposure. The edges of the leaves have minute teeth (serratures). In cross section the leaves show three resin ducts, one in each corner of the section.

The cones (Pls. XVI, XVII), which mature at the end of the second season, are one-sided (oblique) because of the greater development of the scales on one side. They are from 2 to $3\frac{1}{4}$ inches long and externally light yellowish brown, the ends of the cone scales being more or less glossy, but becoming ash-colored with age. The upper sides of the scales are a clear cinnamon-brown, while the lower sides are a deep purplish brown. On one side of the cones the ends of the cone scales have strongly developed, sharp-edged knobs, while on the opposite side the knobs are much less prominent. All of the cone scales terminate in a delicate incurved prickle, which is usually broken off in old, weathered cones (Pl. XVII). As with the closely related western yellow pine, the cones are borne on very short stems, which remain on the branches, with a few of the basal cone scales attached, when the cones fall from the trees. Most of the cones fall during late autumn or winter following maturity and after their seeds are shed. The seeds (Pl. XVII, *a*) are provided with broad wings which are a pale cinnamon-brown. Perfect seeds are borne under all of the cone scales, except the lower 3 or 4 layers, where they are abortive. The number of seed-leaves is unknown at present.

The wood of Arizona pine is similar in general appearance to that of western yellow pine. It has a very thick layer of whitish or very light straw-colored sapwood, the heartwood being a pale reddish yellow. In old trees the wood is especially narrow-ringed and rather soft and brittle. A cubic foot of dry wood weighs nearly $31\frac{1}{2}$ pounds, being slightly heavier than that of western yellow pine. The best

grades of it are suitable for many, if not all, of the commercial uses to which western yellow pine is put. Only very limited local use is made of this wood for lumber¹ in Arizona, chiefly because the tree grows in rough situations difficult of access.

OCCURRENCE AND HABITS.

Pinus arizonica occurs on dry rocky and gravelly slopes, canyon sides, and ridges at elevations between 6,000 and 8,500 feet (map No. 9). It often forms pure, quite dense stands of good saw timber at the lower elevations where the soil is less rocky, while at higher levels it grows in open scattered stands of poor form for timber. Sometimes it is associated with western yellow pine, Apache pine, and occasionally with Chihuahua pine, Arizona cypress, and white-leaf oak.

Arizona pine is intolerant of heavy shade during all periods of its growth, being similar in this respect to the western yellow pine. Seedlings, however, grow well under very light shade for 3 or 4 years. This species bears seed abundantly about every 2 years, but as a rule germination occurs only sparingly in the rougher, rockier situations, though plentifully on broken, exposed mineral soil.

LONGEVITY.

Arizona pine is probably a rather long-lived tree, attaining an age of at least 250 or 300 years. The limited number of trees studied show that those from 20 to 30 inches in diameter are from 115 to 165 years old. Further determinations are necessary, however, to establish the actual limits of age.

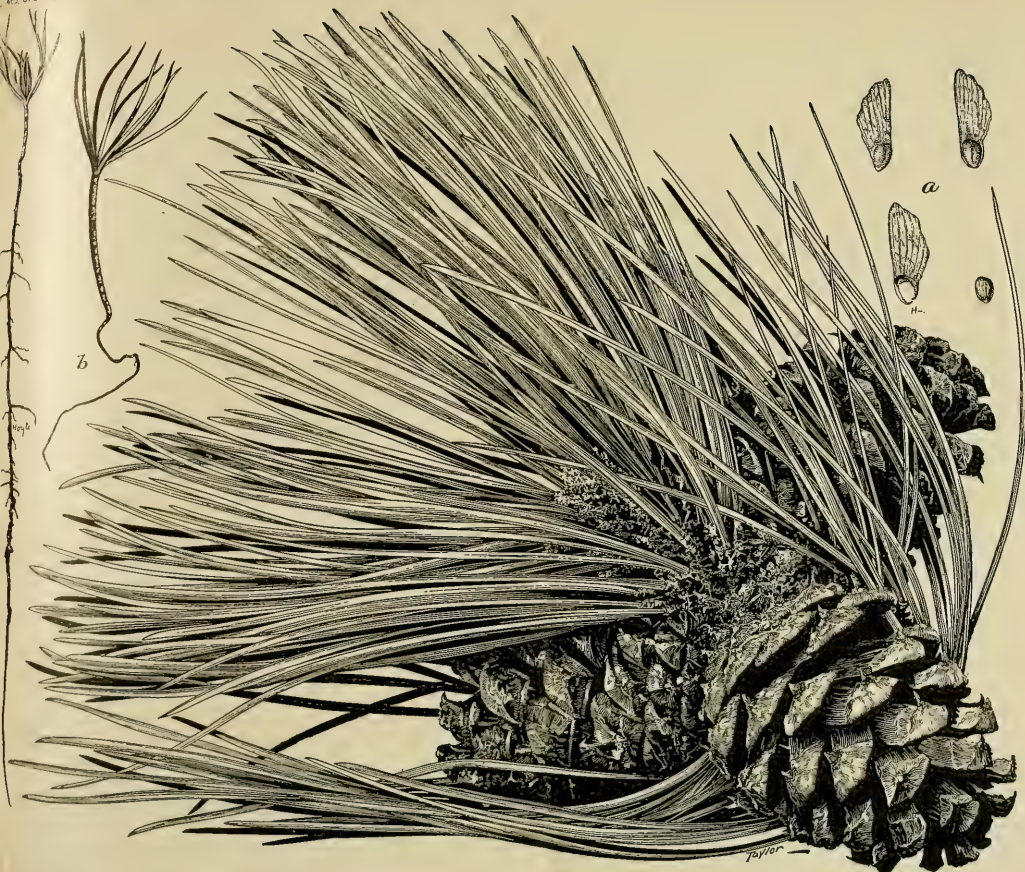
WESTERN YELLOW PINE.

Pinus ponderosa Lawson.

COMMON NAME AND EARLY HISTORY.

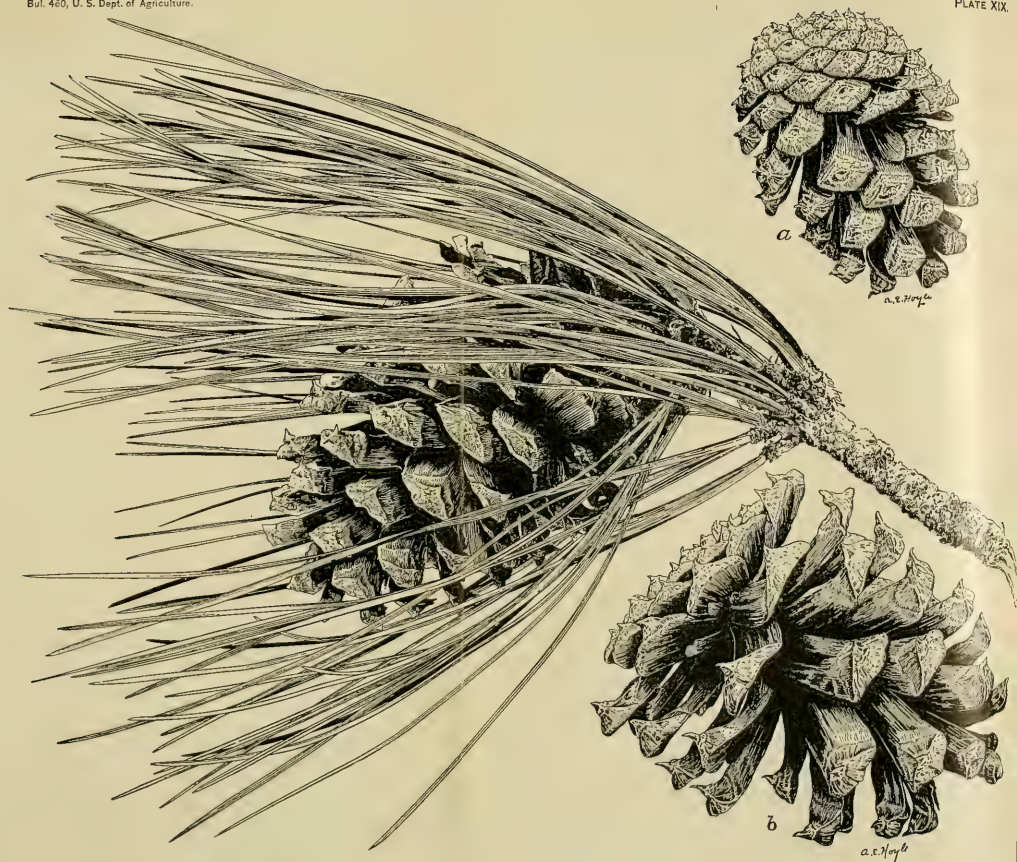
Throughout its wide distribution this tree is generally known as "yellow pine" but sometimes as "bull pine." In order to avoid confusion of *Pinus ponderosa* with other "yellow" pines it became necessary to adopt the common name western yellow pine, which is now accepted quite widely by lumbermen. The technical name *Pinus ponderosa*, which most authors apply only to the big yellow pine of the Pacific slope, is here made to include also the Rocky Mountain

¹ It is probable that this pine is being lumbered to a considerable extent in northern Mexico, along with other hard-wooded and soft-wooded pines. Specimens collected by American prospecting timber operators usually contain Arizona pine, reported to be associated with other Mexican timber pines.



PINUS PONDEROSA: FOLIAGE AND CLUSTER OF OPEN CONES (ATTACHED).

a, Upper (right) and lower sides of seeds with wings and detached seed with its wing; b, seedlings, one and three months old.



PINUS PONDEROSA: FOLIAGE AND SINGLE OPEN CONE (ATTACHED).

a, Detached small form of open cone; b, detached large form of open cone.



PINUS PONDEROSA; SHOWING TYPICAL CROWN FORM OF FULL-GROWN TREE. (ARIZONA.)

form of this pine usually designated as *Pinus ponderosa scopulorum*.¹

The earliest published notice of western yellow pine is in the journal of the Lewis and Clark expedition, which records that in 1804 cones of a pine (now believed to be western yellow pine) were found floating in the White River and doubtless came from a growth of this species in northwestern Nebraska. To David Douglas, however, belongs the credit of having first brought this tree to the notice of dendrologists by his discovery of it in 1826 on the Spokane River, Wash. The following year (1827) he sent seeds to the London Horticultural Society, from which a tree was raised in the Caledonian Horticultural Society's garden.² The first technical description was taken from this tree; and its present name, *Pinus ponderosa*, was established for the first time by Lawson³ in 1836, although David Douglas had previously proposed this name (but without a definite

¹ A long field study of the Rocky Mountain form of the western yellow pine and of the generally longer-leaved yellow pine of the Pacific region has convinced the writer that the two are geographic forms only of one widely distributed species, which was technically described first in 1836 as *Pinus ponderosa*. The Rocky Mountain yellow pine is, therefore, here united as a silvical form with the Pacific slope yellow pine, under the name *P. ponderosa*. The writer can find no constant characteristics to separate satisfactorily the Pacific slope tree from its so-called variety "*Pinus ponderosa scopulorum*" of the central and southern Rocky Mountain region. The most distinctive types of "*P. ponderosa scopulorum*" occur in the Dakotas, Nebraska, eastern Wyoming, adjacent sections of Colorado and in Texas, where the leaves are shorter and the cones smaller than are generally found on trees occurring west of these outlying sections. Short-leaved and small-coned trees are, however, not infrequent in the central and southern Rockies, along with leaf and cone forms that are clearly intermediate between the most eastern and the interior mountain trees. Marked differences in the soil and climatic conditions under which the short-leaved and the longer-leaved trees grow can easily account for the supposed specific and varietal distinctions relied upon to separate the Rocky Mountain yellow pine from the Pacific tree. It seems much wiser to consider the trees of these two regions silvical forms of one variable species than to try longer to maintain them as distinct by characteristics which are clearly only individual variations. Exactly parallel cases are the attempted separations of the Rocky Mountain form of lodgepole pine from the Pacific coast form and of the Rocky Mountain form of Douglas fir from the Pacific slope form, both of which grow under totally different soil and climatic conditions.

² Elwes and Henry (The Trees of Great Britain and Ireland, V, 1074, 1910).

³ Agric. Manual, 354, 1836. The Pacific slope form of *Pinus ponderosa* appears to be well adapted to the climate of England, where, according to Elwes and Henry (opus cit., 1076), several trees raised from Douglas's seed, sent in 1827, and planted in 1829, were living in 1909 and had attained heights of from 96 to 104 feet, with diameters of from about 26 to 35 inches. Many other trees planted since then are said to be in thriving condition. As might well be expected, it is successfully grown there only in well-drained soils. The German Government in the early nineties imported considerable quantities of seed of the Pacific slope form of this tree for experiments in forest planting. The stock raised grew well for several years and then died from some unknown cause (Schwappach, Anbau. Fremdl. Holzart., 57, 1901). Presumably, however, the Rocky Mountain form would have proved to be adapted to German conditions. Trials of both the Pacific slope and the Rocky Mountain form of *Pinus ponderosa* in the region of New England have not been successful (fide, Sargent, Gard. and For., 470, 1897). It is too early yet to predict the success of this tree set in forest experimental plantations in the Letchworth Park Forest and Arboretum at Portage, Wyoming County, N. Y., where so far, however, 3 to 5 year old stock raised from Rocky Mountain seed is in thrifty condition and promises to grow well. A single tree now standing in the grounds of the U. S. Department of Agriculture, Washington, D. C., raised from seed collected in the Pacific slope region, was planted here about 30 years ago by William Saunders. Its growth has, however, been exceedingly slow, the height being about 15 feet.

description of the tree's characteristics) in his account of the discovery of the species published in 1836.¹

The botanical history of western yellow pine is full of perplexities. During the three-quarters of a century the tree has been known, no less than 15 different technical names have been applied to different or the same forms of the tree, some of which were described as distinct species and others as varieties. Much, if not all, of this confusion is probably the result of a study of herbarium specimens only, rather than of the tree as it grows under the different soil and climatic conditions within its extensive range (Map No. 10).

DISTINGUISHING CHARACTERISTICS.

Pinus ponderosa is a massive, straight-trunked tree with a long, narrow, open crown of hugely developed, bent branches. The narrow columnar form of the crown, with its scattered branches, upturned at their ends, is very characteristic. Often one or two large lower branches are separated from the crown by 20 or more feet of clear trunk. Trees grown from the first in an open stand usually bear branches close to the ground, retaining this long, low crown throughout life (Pl. XX). The trunk is cylindrical, with little taper until the large crown branches are reached. Its majestic size is surpassed by no other native pine except the sugar pine of California. In general the height is from 125 to 140 feet, with a practically clear trunk of from 40 to 60 feet, and a diameter of from 3 to 5 feet. Unusually large trees are from 150 to 180 feet high, while trees are said to have been found over 200 feet high. The largest diameter recorded is about 8 feet. The form of western yellow pine found in the central and southern Rockies ranges from 60 to 125 feet in height and from 20 to 30 inches in diameter, or occasionally somewhat larger. The bark of old trunks is marked by very broad, shield-like, russet-red plates, which may be from 3 to 4 inches thick, especially near the base of the tree. The bark is peculiarly made up of small, concave scales. Younger trees, up to 2 feet in diameter, are quite unlike older ones in having dark red-brown or blackish, narrowly furrowed bark.² Young shoots, which have a strong odor of orange when broken, are yellowish green and later brownish.

¹ Companion to the Botanical Magazine, ii, 111. 1836.

² Lumbermen in the range of western yellow pine distinguish two forms of the species, one of which they call "black jack" and the other "yellow pine." The two forms are botanically alike, but distinguished by striking differences in the color and markings of the bark, which appear to be due entirely to age. Trees up to about 150 years of age commonly have blackish, narrowly ridged bark and are, therefore, known as "black jack," while trees older than these usually have light reddish-brown bark broken into broad, flat ridges, such trees being called "yellow pine." The young growths of several eastern pines are also distinguished as "black jack," most lumbermen who apply the name knowing, however, that it is an age designation rather than one of species.

The foliage, borne in heavy brush-like clusters at the ends of bare branches, is a deep yellow-green. The leaves (Pls. XVIII, XIX) occur in bundles of 3 (sometimes of 2 and rarely of 4 and 5, and then chiefly on saplings). They vary in length from about $4\frac{3}{4}$ to $11\frac{1}{4}$ inches. Each season's growth of leaves remains on the tree about three years. The edges of the leaves have minute teeth (serratures). A cross section of the leaves shows from 2 to 5 resin ducts, the usual number being 2.

The cones (Pls. XVIII, XIX) mature early in August of the second season and shed their seeds mainly during September. The cones of some trees are a bright grass green when mature, while those of other trees are a dark purple, there being no other essential difference between trees bearing cones so dissimilar in color. Cones vary in length from $2\frac{3}{4}$ to about $5\frac{3}{4}$ inches and in width from $1\frac{1}{2}$ to about 2 inches. The ends of the cone scales are russet-brown and shiny. After the seeds are shed, the cones begin to fall, and by early winter they are all down. A notable characteristic of the cones of this pine is that when they break away from the branch some of the basal scales are left on the tree. The seeds (Pl. XVIII, *a*), which vary greatly in size, are marked with purple spots and blotches on a dull yellowish ground, while the wings are a light purple-brown. The number of seed-leaves varies from 5 to 9 (Pl. XVIII, *b*).

Western yellow pine wood is narrow-ringed, the rather thick layer of sapwood being nearly white and the heartwood ranging from a pale lemon-yellow to an orange-brown or a reddish yellow. It varies greatly in texture according to the age of the tree. Young trees have moderately hard, resinous, strong wood; the wood of old trees is brittle, only slightly resinous, and very soft—so much so that lumber cut from such trees is sold as "white pine." In general a cubic foot of dry wood weighs from about $28\frac{3}{4}$ to $29\frac{3}{4}$ pounds. The weight of wood from very old, slowly grown trees would probably not exceed about 25 pounds per cubic foot. It is one of the most valuable commercial woods produced in the Rocky Mountain region, being used for all sorts of dimension timber under cover, for interior and exterior work, railroad ties, mining timber, fuel, etc. It is, however, only moderately durable in contact with earth or when exposed to the weather in an unprotected state.

OCCURRENCE AND HABITS.

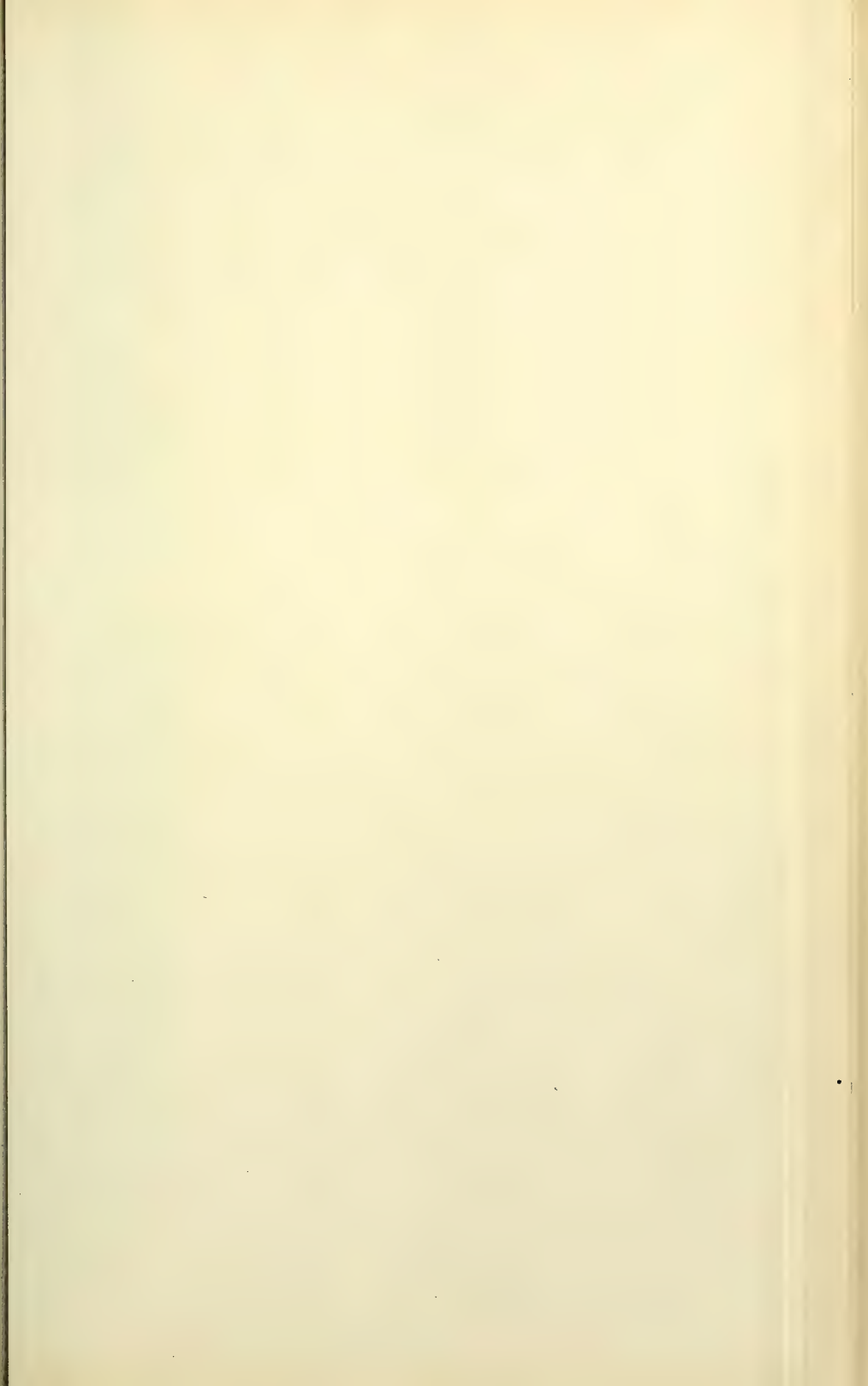
Western yellow pine occurs on dry and moist slopes, on the tops of ridges and in canyon bottoms, in general at elevations between 1,800 feet (Pacific region) and 10,300 feet (southern Rockies), the main forest growth in the Rocky Mountain region being found be-

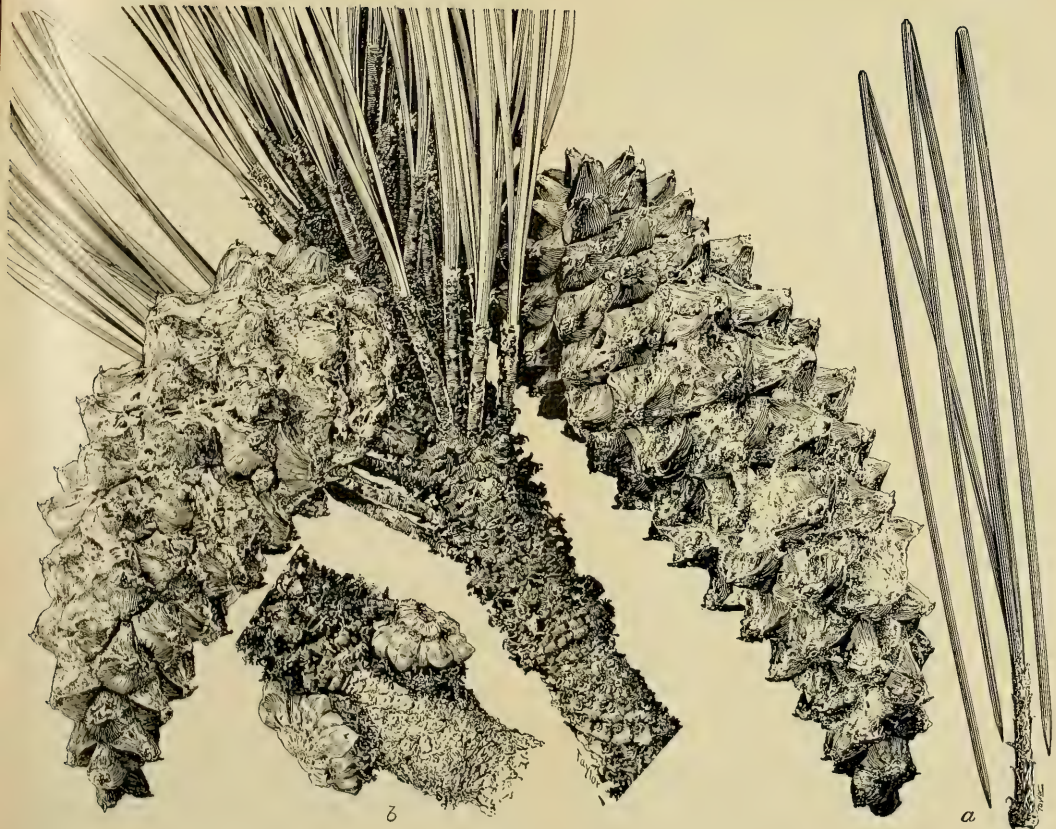
tween 5,000 and 8,500 feet (Map No. 10). It is very moderate in soil requirements, growing on all soils from glacial drift and volcanic ash to deep, loose sands and stiff clays. Dry, well-drained sandy or gravelly soils are, however, most characteristic. Once established, it requires very little moisture in the upper layers of earth; for the enormously deep roots enable it to thrive in soils apparently as dry as those in which piñon pines and junipers grow.

Pure extensive stands are formed; and it occurs also in mixture occasionally with broad-leaved trees, but more commonly with western larch, Douglas fir, and white fir, and sometimes with Arizona pine and Mexican white pine. Open grassy park lands are often interspersed, and, as a rule, little or no underbrush, or even grass, occurs in these forests because of frequent fires.

Pinus ponderosa demands an abundance of light throughout its life, particularly after the pole stages. Young stands may remain dense for from 10 to 15 years, but subsequently they thin out rapidly. Trees above 20 feet in height require almost unbroken light. Those in mature stands are rarely closer than 30 feet, and the crowns seldom touch. In the South, however, seedlings do not endure intense light and heat, usually coming up in the shade of old trees, or in openings near logs, boulders, and brush which afford slight protection. In the North, where the light is less intense, they grow commonly in unprotected openings.

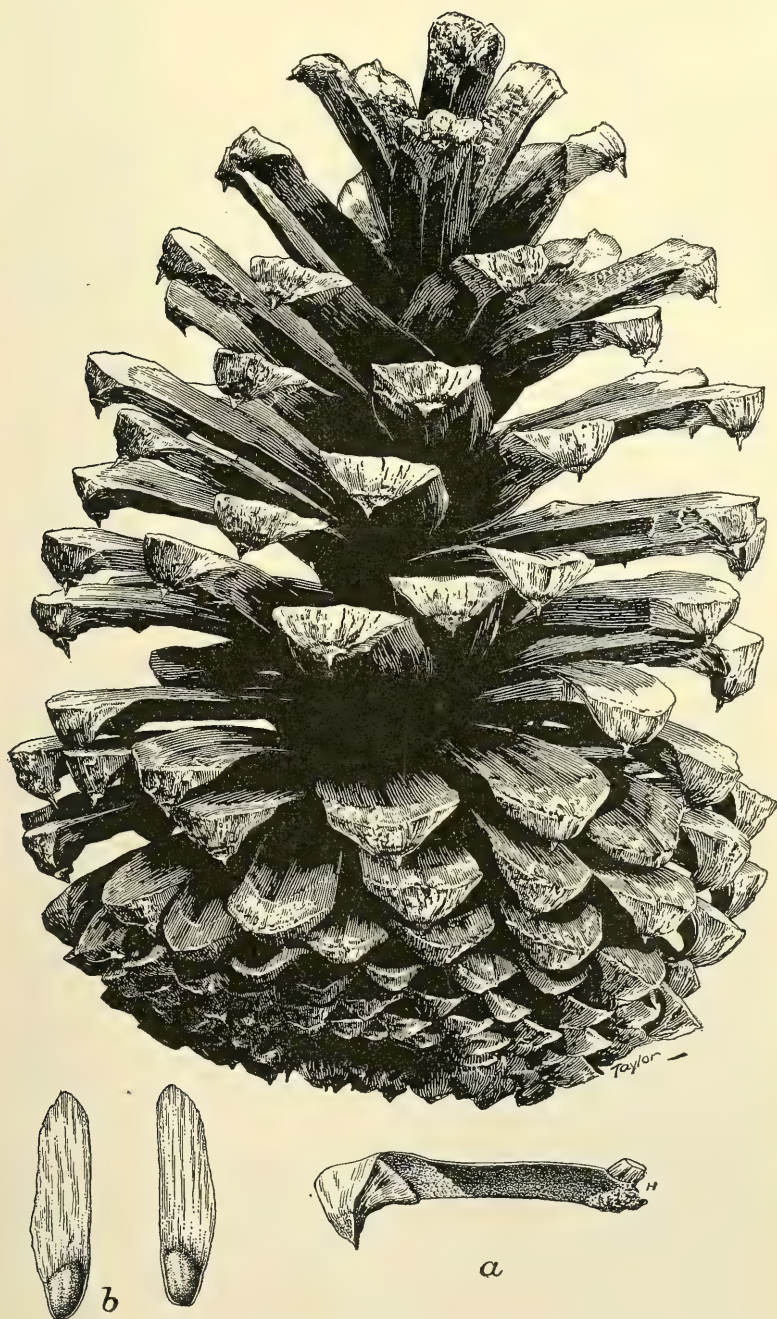
Pinus ponderosa is a frequent and abundant seeder. Cones are locally produced about every year, so that there is always some seed in a forest; but specially good seed years occur only at intervals of from 3 to 5 years. Germination from natural dissemination, in which much of the seed fails to come in contact with mineral soil, is usually about 50 per cent; while germination from artificial sowing, in which the seed is in close contact with the soil, is from 60 to 80 per cent. Well-drained, fresh soils, and a moderate daily range of temperature are necessary for germination. Trees from 20 to 25 years old produce seed; but generally the quantity is limited and the quality poor until the trees are about 50 years old. Large, thrifty trees produce over 1,000 cones, the average amount of seed per tree amounting to from 1 to 6 pounds. The seed is not wafted far from the mother trees in the closer stands, but in open ones it may be carried by the wind for from 500 to 700 feet. A mature tree can seed about one-fourth of an acre in a good seed year. Squirrels and birds eat considerable quantities of seed. The rodents, however, disseminate some seed as a result of their habit of storing it for food; but reproduction from this source is accidental. Much seed is washed down steep slopes to stream beds and depressions, where good reproduction often occurs.





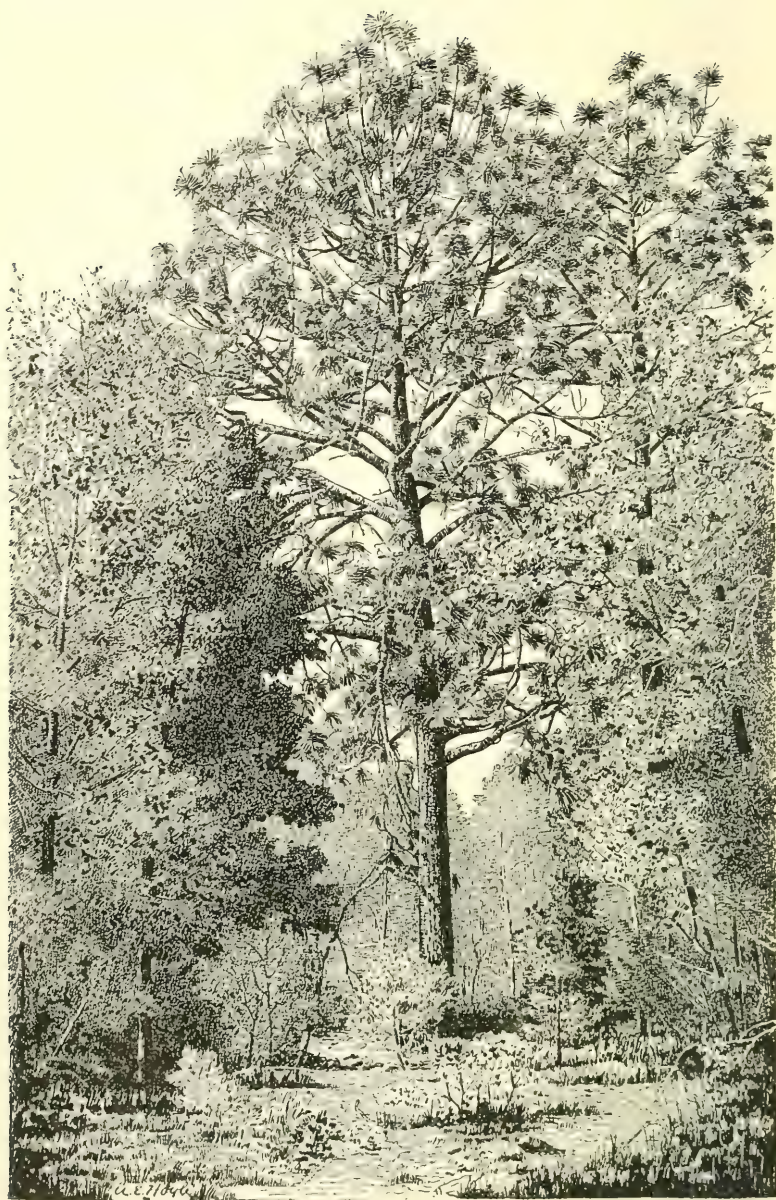
PINUS APACHECA: FOLIAGE AND RIPE CLOSED CONES.

a, Detached leaf bundle; b, part of branch showing basal scales of mature cone that has fallen away.

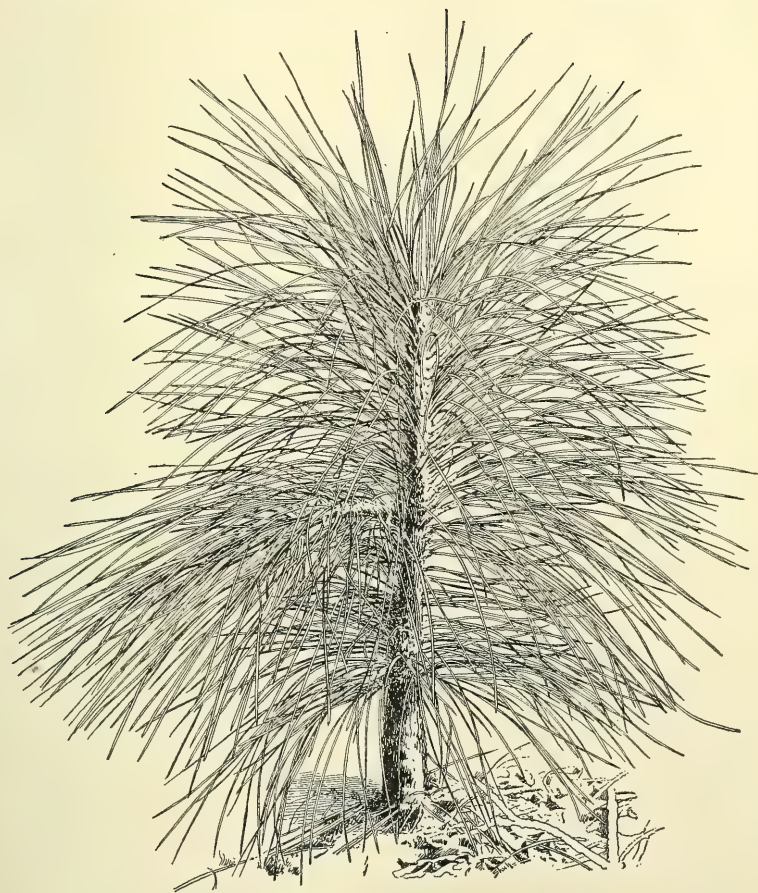


PINUS APACHEA: DETACHED OPEN CONE.

a, Detached cone scale (side view); *b*, upper side of seeds with wings.



PINUS APACHEA: SHOWING CROWN FORM IN OPEN STAND; 40 FEET HIGH AND 20 INCHES IN DIAMETER.



PINUS APACHECA: YOUNG TREE (SIX YEARS OLD) 30 INCHES HIGH.

LONGEVITY.

Western yellow pine is in general a long-lived tree, attaining an age of from 350 to 500 years. In the central and southern Rocky Mountain region, it appears to be shorter-lived than in the northern part of this region and on the Pacific slope, trees in the central and southern regions probably not attaining an age of over 250 or 300 years.

APACHE PINE; "ARIZONA LONGLEAF PINE."

Pinus apachea Lemmon.

COMMON NAME AND EARLY HISTORY.

This comparatively rare species is practically unknown to settlers and other laymen, with whom, for the most part, it passes as "yellow pine." The name "Apache pine," derived from the technical specific name, is a book name probably not yet used in the field, but one which may be appropriately adopted. "Arizona longleaf pine" has been applied by United States forest officers in the Arizona range of the tree, but as the species occurs elsewhere in our Southwest this name would seem to be inappropriate.

Until recently Apache pine (*Pinus apachea*¹) and the Mayr pine (*P. mayriana*) were believed to be distinct species. The writer is now convinced, however, that they are one species, which is distinct from other southwestern pines.² Dr. J. G. Lemmon discovered *Pinus apachea* in 1881 in the Chiricahua Mountains, Arizona, and under this name he published a figure and description of it in 1894. Dr. Mayr next found it in 1887 in the Santa Rita Mountains, Arizona; and in 1889 it was described and named "*Pinus latifolia* Sargent," which, being found to be a synonym, was replaced in 1897 by "*Pinus mayriana*."³ As Dr. Lemmon's name, *Pinus apachea*, was published

¹ Erithea, II, 103, Pl. III. 1894. (See also footnote 1 in the present work, on p. 34.)

² *Pinus apachea* appears to be closely related to *Pinus engelmanni* Carrière, which is a Mexican species not known to occur in the United States. Dr. George Russell Shaw relates the Apache pine to our western yellow pine under the varietal name "*P. ponderosa* var. *macrophylla*," a name which appears to be preoccupied by Lindley's *Pinus macrophylla* published in 1839, the latter now being considered a synonym of *P. montezumae* Lambert (1803). Later comparative study may possibly show that *P. apachea* is a northern form of *P. engelmanni* Carr. In describing the latter tree Dr. Engelmann, who first characterized it as a new species, unfortunately under the preoccupied name *P. macrophylla*, mentions the close resemblance it bears to *P. australis* (= *P. palustris*). In the opinion of the present writer the general appearance of the two trees is strikingly similar; and, as is shown further on, the seedling growth (Pl. XXIV) of *Pinus apachea* and *P. palustris* is very much alike and equally unlike the early growth of any other southwestern pine.

³ Nomenclature of the Arborescent Flora of the United States (Bull. 14, Division of Forestry), 21. 1897.

3 years before *P. mayriana* Sudw.¹ appeared in print, it would seem that the tree must now be known by the earlier established name, *P. apachea*.

DISTINGUISHING CHARACTERISTICS.

The general appearance of the large, long, deep-green leaves of Apache pine distinguish it from all associated species, and remind one of the southeastern longleaf pine (*P. palustris*). Young trees (from 5 to 6 years old and from 2 to 3 feet high) are also strikingly similar in appearance and habit to the early growth of young longleaf pines (Pl. XXIV).² The crown and trunk form of large trees is, however, similar to western yellow pine. Such trees have rather open, elongated, or round-topped crowns, and straight trunks clear of limbs for from one-third to one-half their height (Pl. XXIII). Young trees (Pl. XXIV) have broadly conical, rather compact crowns and trunks clear of branches for about one-fourth their height. Mature trees are from 50 to 75 feet high and from 14 to 30 inches in diameter. Doubtless larger trees occur. The bark of both old and young trunks is rather narrowly and deeply furrowed, the main ridges being connected by smaller side ridges. It varies in thickness from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches. Externally the bark is dark brown, newly opened rifts showing dull red-brown.

The stout dark-green leaves (Pl. XXI, *a*), which bear minute teeth (serratures) on their margins, occur mainly in bundles of 3 (exceptionally of 2, 4, and 5) and are commonly from 8 to 15 inches long, some trees bearing leaves 6 to 7 inches long. A cross section of the leaves shows from 11 to 14 resin ducts. Each season's growth of leaves remains on the tree about 2 years. The basal sheaths of the leaf-bundles, at first light brown and later dark brown, are from three-fourths of an inch to $1\frac{1}{2}$ inches long and have conspicuously fringed margins.

The cones (Pls. XXI, XXII), matured at the close of the second season, are commonly from 4 to $5\frac{1}{2}$, or sometimes nearly 6, inches long and externally a light yellowish or clay-brown, unexposed parts of the cone scales being a dark chocolate-brown. They are more

¹ The history of this species is as follows: Dr. C. S. Sargent first described it as *Pinus latifolia* (Gard. and For. II, 496, fig. 135, 1889) from specimens collected by Dr. Mayr while exploring our Southwest. Later, the present writer found the specific name "*latifolia*" to be preoccupied in previously published trinomials applied to two different pines, thus making it impossible to retain longer *P. latifolia* for the Arizona pine. The latter was, therefore, renamed *P. mayriana* in 1897, in honor, as was then supposed, of its first discoverer, Dr. Heinrich Mayr. This name must, however, now become a synonym of *Pinus apachea* Lemmon, which appears to be the first name applied to the tree. Dr. Sargent's present judgment is that the "Mayr pine" is a variety only of the western yellow pine and he has accordingly designated it as *P. ponderosa mayriana* (Silva, XI, 81. 1897).

² The tap-root of seedlings descends to great depth during the first 5 or 6 years; while the stem above ground grows very slowly in height, and rarely branches. In this habit of growth, young plants differ greatly from the western yellow pine and Arizona pine, and strongly resemble the longleaf pine (*Pinus palustris*) in its first few years' growth.

or less one-sided (oblique), which is due to the greater development of scales on one side (Pl. XXI). In falling from the branches the cones leave a few basal scales attached to the limbs (Pl. XXI, *b*), as in the case of *Pinus ponderosa* and other yellow pines of this group. The ends (umbos) of the cone scales are recurved, elongated (especially on the fuller side of the cone), sharply two-sided, the extreme ends being contracted abruptly to a short delicate prickle (Pl. XXII, *a*). The seeds (Pl. XXII, *b*), are a dark chocolate-brown (deeper on the lower side) and from about five-sixteenths to three-eighths of an inch long. Perfect seeds are produced chiefly in the middle third of the cone, many scales bearing only one seed. The seed-leaves vary from 8 to 10, averaging about 9.

The wood of Apache pine is rather heavy (actual weight undetermined), hard, somewhat "cross-grained," and uniformly wide-ringed, the darker bands of late wood forming from one-third to about one-half the annual layers of growth. The wide-ringed character of this wood is due probably to the fact that the trees usually grow in scattered open stands where an abundance of light stimulates diameter growth.

OCCURRENCE AND HABITS.

Pinus apachea grows in the rocky gravelly soils of benches, gulches, and gentle slopes, at elevations of from about 5,700 to 8,200 feet, and usually in moderately moist situations (map No. 11). It forms a very open stand or is widely scattered, and is associated more or less with Arizona pine, Chihuahua pine, western yellow pine, Arizona oak, whiteleaf oak, and huckleberry oak.

It is intolerant of shade except during the first five or six years of its life.

Apache pine bears abundant crops of seed; good seed years occur only at intervals of about two or three years, but some seed is produced practically every year in parts of the tree's range. Wind carries the large-winged seeds (Pl. XXII, *b*) several hundred feet from the parent trees, but as many of them fall where germination can not occur for lack of soil cover, reproduction is not abundant and is always scattered. Reproduction occurs most readily on broken and washed mineral soil. The seeds of this pine are favorite food of birds and rodents, which consume large numbers of them.

LONGEVITY.

The age limit of Apache pine is imperfectly known at present, but the tree probably attains an age of from 175 to 200 years. Trees from 15 to 18 inches in diameter are from 65 to 90 years old, and trees 20 to 28 inches are from 100 to 140 years old. Between the ages of about 8 and 75 years this pine appears to grow rapidly in height and diameter.

CHIHUAHUA PINE.

Pinus chihuahuana Engelm.

COMMON NAME AND EARLY HISTORY.

Chihuahua pine is a little-known species which has no distinctive common name in the United States, probably because it is not often distinguished by laymen from the other yellow pines with which it is more or less associated in our Southwest (map No. 12). It is known to a few lumbermen in Mexico as "black shortleaf pine." The name "Chihuahua pine," derived from the specific technical name, is suggested here as appropriate, because the tree occurs extensively in Chihuahua, Mexico.

Pinus chihuahuana was discovered in the western part of Chihuahua by Dr. A. Wislizenus in 1846, and in 1851¹ Dr. J. M. Bigelow, a botanist of the Mexican Boundary Survey Expedition, was the first to find it in our Southwest (vicinity of Copper Mines, southern New Mexico).² Chihuahua pine was technically named and described as a species for the first time in 1848; from then until 1909 there has been a general agreement among botanists regarding its claim to specific rank. In 1909 Dr. G. R. Shaw,³ believing it to be a variety of the Mexican *Pinus leiophylla* Schl. and Cham., designated it as *P. leiophylla* var. *chihuahuana*. He based the relationship upon the triennial fructification⁴ of these two pines, and also upon the habit both have of sprouting from the stump.⁵ Chihuahua pine is here maintained as a distinct species because of the commonly constant occurrence of its leaves in clusters of 3, the leaves of *P. leiophylla* occurring almost invariably in clusters of 5.

DISTINGUISHING CHARACTERISTICS.

Chihuahua pine is a small or medium-sized tree as it occurs in our Southwest, varying from 35 to 60 feet in height and from 1 to 2 feet in diameter. The fairly straight trunks are clear for one-half or two-thirds of their length, and the usually large branches have an upward trend, forming a narrow pyramid-shaped crown. Compared with other associated yellow pines the foliage appears thin and pale. The trunk bark, composed of thin, closely adhering scales, varies from a blackish brown to a very dark brown and is commonly bright red-brown in the deep rifts. It is from about seven-eighths

¹ Fide Sargent, Silva, XI, 86, 1897.

² Fide Torrey, Botany of U. S. and Mexican Boundary Survey, 209, 1858.

³ The Pines of Mexico, 14, 1909.

⁴ Dr. George Engelmann and Prof. C. S. Sargent discovered in 1880 that *Pinus chihuahuana* requires 3 years in which to mature its cones (Botanical Gaz., VII, 4, 1882).

⁵ Chihuahua pine sprouts freely from stumps in its range within the United States; but the writer hesitates to rely upon this as a dependable indication of relationship to the Mexican *Pinus leiophylla*, for the reason that the sprouting propensities of *Pinus echinata*, *P. rigida*, and *P. pungens*, at some ages and under some conditions, could hardly be relied upon to show varietal relationship of these pines.



PINUS CHIHUAHUANA.

a, Foliage and close cones, b, detached 3-leaved and 5-leaved bundles; c, open cones, d, upper (right and left) and lower (center) sides of seeds with wings.

of an inch to $1\frac{1}{2}$ inches thick, deeply and narrowly furrowed, and with long, wide, interrupted ridges.

The slender, bluish-green or grayish-green leaves (Pl. XXV, *b*) occur in bundles of 3 (occasionally of 4, and exceptionally of 5), and when full grown are without basal sheaths (common to other associated yellow pines). The short, papery, scaly sheaths of immature leaves remain attached only until the end of the first summer or autumn. Mature leaves are from 2 to $4\frac{1}{4}$ inches long, but usually about 3 inches. The edges of the leaves have minute, distinct, sharp teeth (serratures). A cross section of the leaves shows two resin ducts. Each season's growth of leaves persists for about 3 years, being shed during the fourth season.

The cones (Pl. XXV, *a, c*), matured in September of the third season,¹ are from about $1\frac{1}{2}$ to $2\frac{5}{8}$ inches long, and are borne on a short, rather slender, curved stem from three-eighths to five-eighths of an inch long (Pl. XXV, *c*). Mature cones are at first a light, yellowish brown, later becoming dull gray by exposure to the weather. Unexposed parts of the cone scales vary from a light to a deep purple brown. The slightly thickened ends of the cone scales have a low, sharply defined ridge and bear delicate prickles, which gradually disappear as the cones become older. Mature cones adhere to the trees 5 or more years, and when they fall they usually retain their stems. The chocolate-brown seeds (Pl. XXV, *d*) have pale yellowish-brown wings delicately splashed with darker brown. The number of seed-leaves is unknown at present.

In general the wood of Chihuahua pine is moderately narrow-ringed and straight-grained and rather hard. The light straw-colored, thick layer of sapwood, containing from 50 to 60 annual layers of growth, contrasts strongly with the reddish-yellow heartwood. A cubic foot of dry wood weighs about 34 pounds, being considerably lighter than that of western yellow pine but having its good working qualities. The best grades are equal to western yellow pine for commercial purposes. The comparatively small size and limited supply of this tree available in our Southwest, however, prevent it from being used for lumber.²

OCURRENCE AND HABITS.

This species occurs on dry, rocky, gravelly mountain slopes and benches at elevations between 5,500 and 8,200 feet (map No. 12). The thrifty growth of this tree in moist and rich soils shows that it can profit by such favorable conditions, the growth in drier situa-

¹ *Pinus chihuahuana* is exceptional among western pines in that its male and female flowers do not appear until July, which is much later than in the case of other pines of its range.

² The Chihuahua pine attains large dimensions in Mexico, where it is probably being lumbered along with such associated timber pines as *Pinus arizonica*, *P. ponderosa*, and *P. strobtiformis*.

tions being much less vigorous. It forms pure open stands of limited extent (in the United States) and is also scattered among open forests of Arizona pine, western yellow pine, and occurs occasionally with Apache pine. Its requirement of light is very similar to that of the western yellow pine.

Chihuahua pine bears good crops of seed about every other year, but some cones are ripened practically every year. Reproduction is, however, generally sparse, which is due in part probably to the fact that mature cones often remain closed for several years, thus failing to liberate their seeds regularly.

LONGEVITY.

Chihuahua pine is moderately long-lived, probably attaining an age of from 250 to possibly 300 or more years. Further determinations are required to establish its extreme age. Trees from 14 to 20 inches in diameter are from 125 to 185 years old.

LODGEPOLE PINE.

Pinus contorta Loudon.

COMMON NAME AND EARLY HISTORY.

Lodgepole pine is one of the most interesting of our native species on account of its variable characteristics and its enormously wide range (map No. 13), which extends from sea level to 11,500 feet elevation. For many years authors have endeavored to maintain that the form of lodgepole pine which inhabits the region from our northern Pacific coast to the western Cascades is distinct from the lodgepole pine that grows on the high Sierras and Rocky Mountain plateaus. The first is known to botanists as *Pinus contorta* and the last, as *Pinus murrayana* and *Pinus contorta murrayana*. The distinctions assembled to separate these trees are, however, one after another broken down when living trees are carefully studied throughout this great region. In the opinion of the writer such distinctions as differences in thickness of bark, size of cones and leaves, or size and form of the tree, may, in the case of these two forms, be consistently within the variations of one polymorphous species. Moreover, the reproductive organs of these supposedly distinct trees being essentially the same, they offer no characteristics on which to base varietal or specific distinction. Perhaps no other North American trees have given so much trouble, or left so much uncertainty in the minds of those who have attempted to hold them separate, as the coastal and high-mountain forms of this pine. Recent students of trees certainly have appreciated the lack of distinction between these two regional forms, but have been slow to depart from the time-honored judgment of earlier writers. It is confidently believed, however, that the latter would have taken the broader view had they been able to study the trees as they grow in all their retreats.

The Pacific coast form of this species is commonly called "scrub pine," because it is stunted, and sometimes "sand pine" and "shore pine," owing to the fact that the tree grows on the sandy seashore. The high-mountain form, however, particularly of the Rocky Mountain region, is most widely known as lodgepole pine, a name which is descriptive of the trunk form over most of the tree's great range and therefore appropriate. "Tamarack," "spruce pine," and "Murray pine" are local names also applied to the mountain form of this species.

The high-mountain form of this tree is believed to have been discovered by Lewis and Clark¹ in 1805 on mountains above the headwaters of Jefferson River (in the present Absaroka National Forest), western Montana, while the Pacific coast form is said to have been discovered by David Douglas in 1825 near the mouth of the Columbia River in Washington. The first technical name of this tree, *Pinus contorta* Loudon, was published in 1838. The accompanying description was based on the stunted Pacific coast form raised from seed which David Douglas introduced into England in 1831.² The high-mountain form of lodgepole pine was first described and named "*Pinus murrayana* Oregon Committee" in 1853 and was found by John Jeffrey in 1852 in the Siskiyou Mountains, northern California. Ever since it was proposed to separate these two geographic forms of lodgepole pine the botanical history has been exceedingly complicated and includes the application by different authors of some 15 specific and varietal names, together with several erroneous references of the tree to other distinct species of two-leafed pines. Wide variation in the size of the cones and in the leaves has, for the most part, been the basis of confusion, which the present writer believes is best and properly cleared up by uniting all forms of the tree as one species.³

¹ History of expedition under command of Lewis and Clark, II, 457 (ed. Coues). It is believed that the pine mentioned in the narrative of these explorers, "a small species of pitch pine with a short leaf," could be no other than our lodgepole pine.

² Fide Sargent, Silva, XI, 93, 1897.

³ The high-mountain form of lodgepole pine was introduced into cultivation in England in 1853 and 1854 by John Jeffrey, who sent seeds from the California Sierras (fide Elwes and Henry, op. cit., 1138, 1910). The Pacific coast form did not appear in cultivation there until 1885, when it was catalogued by Lawson as "*Pinus Mackintoshiana*" (Masters, Journ. Linn. Soc. (Bot.) XXXV, 647, 1904), although Douglas discovered the tree in 1825. Both forms appear to be hardy in England, where Elwes and Henry (l. c.) mention trees ranging in height from 40 to 59 feet. One tree grown from seed of the coast form attained a height of 28 feet in 20 years, while examples of the high-mountain form reached a height of 30 feet in 25 years. Both forms of lodgepole pine are said to be cultivated in Belgium; and extensive trials of them for forest planting are being conducted in Germany, where, however, this tree is reported to be affected somewhat by frost when planted in moist situations. Prof. C. S. Sargent (Gard. and For. X, 471, 1897) states that trees from Colorado planted in the Arnold Arboretum, near Boston, Mass., about 1877 have proved hardy in New England. The interior high-mountain form of this species was extensively planted in forest stands at the Letchworth Park Forest and Arboretum, in Wyoming County, N. Y., from 1912 to 1914, and so far the young stock appears to be adapted to the soil and climate there. It is, however, too soon to judge of its fitness and value as a forest tree for that region. For ornamental planting lodgepole pine has little to commend it because of the open appearance of the crown and its short, unattractive leaves.

DISTINGUISHING CHARACTERISTICS.

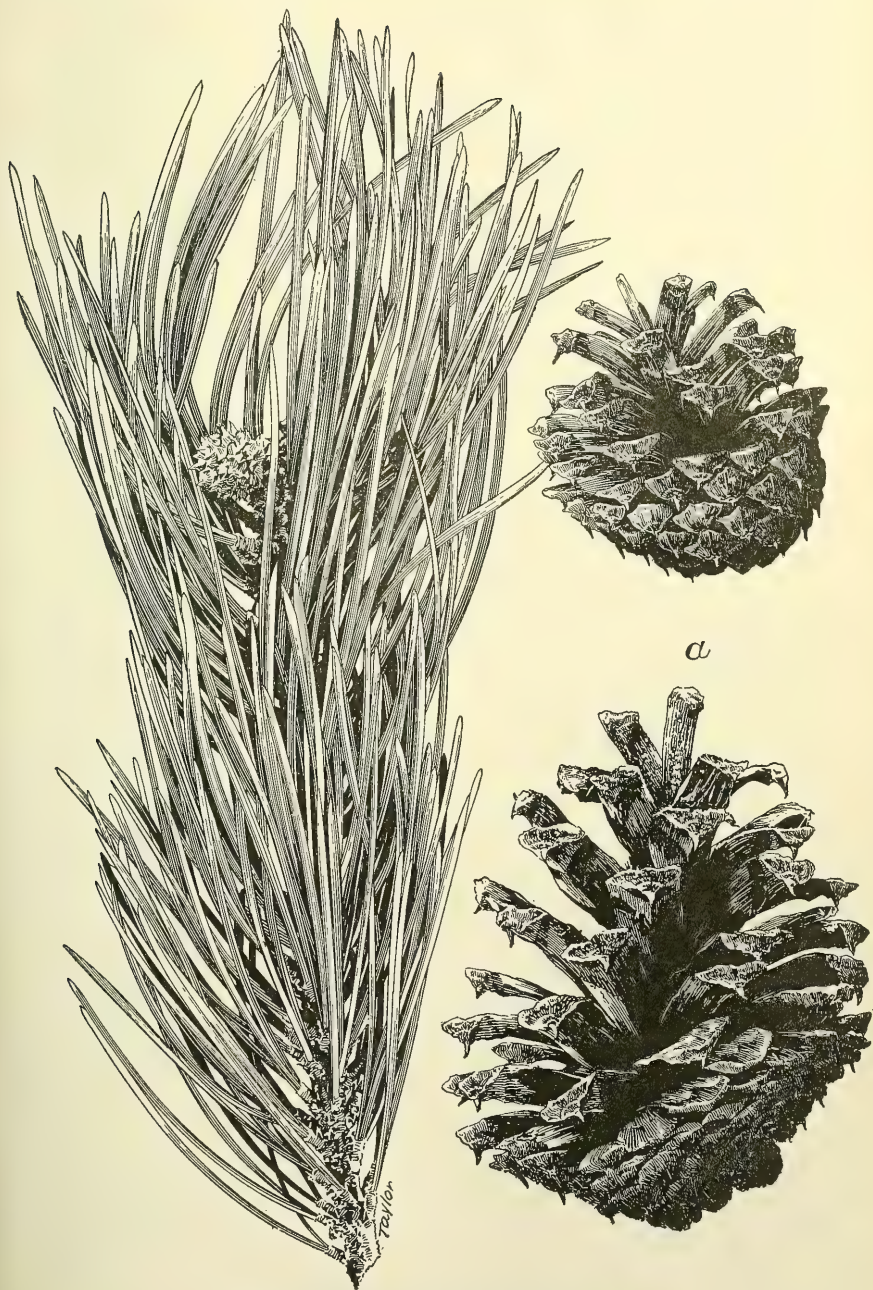
In the Pacific slope region this pine grows in rather open stands and forms a dense rounded or pyramidal crown of large, much-forked branches which often extend down to the ground. In its high mountain range within the Rocky Mountain region it grows in very close stands and develops a tall, clean, slender shaft with a short, rounded, small-branched crown. This characteristic form in its more eastern range has given the tree the name of "lodgepole pine." The thin scaly trunk bark is pale brown with a grayish tinge. In close stands the height is from 50 to 100 feet, the usual diameter being from 12 to 24 inches. Taller and larger trees sometimes occur. The smooth looking trunks are clear of branches for from 30 to 60 feet.

The foliage is a bright yellow-green. The leaves (Pls. XXVI, XXVII) are borne in bundles of 2 and are nearly one-eighth of an inch wide and from about 1 inch to nearly 3 inches long, but usually they are about 2 inches long. Each season's growth of leaves remains on the trees for from 6 to 8 years. Young trees, however, sometimes retain their leaves for 9 years. The edges of the leaves bear minute sharp teeth (serratures). A cross section of the leaves shows one or two resin ducts.

The cones (Pls. XXVI, XXVII) ripen late in August and September of the second season. On many trees, the cones open in late autumn and shed nearly all of their seeds, while the cones of other trees in the same locality may remain closed for a number of years. The cones adhere to the branches for a great many years, some of the closed ones finally opening and liberating their seed.¹ When the cones are fully ripe the tips of their scales are shiny and of a clay-brown color, the inner or unexposed portion being a bright purple-brown. The seeds (Pl. XXVII, *b*) are a deep reddish-brown, with black-brown spots. The seed-leaves vary in number from 3 to 6, but usually there are 5 (Pl. XXVII, *a*).

The wood of trees grown in dense stands, as in the Rockies, is extremely narrow-ringed; while that of trees in open forests, as in the Pacific region, is moderately wide-ringed. The thick layer of sapwood is almost white and the heartwood is of a clear yellow or yellowish-brown color; the heartwood of the Pacific coast form is usually pale brown tinged with red. The wood is rather hard, stiff, and straight-grained. A cubic foot of the dry wood of the Pacific

¹ The wonderful reproductive power of this species on areas over which it has been killed by fire is dependent upon the ability of the closed cones to endure a fire which kills the trees without injuring their seeds. After fire, the cones open, shed their seeds on the bared ground, and a new growth springs up. Another remarkable adaptation insuring this tree against extinction by fire is its habit of producing fertile cones at the early age of from 7 to 10 years.



PINUS CONTORTA: FOLIAGE AND IMMATURE CONE.

a, Detached open cone.



PINUS CONTORTA: FOLIAGE AND OPEN CONES (ATTACHED).

a, Seedlings one month old; b, upper (left) and lower sides of seeds with wings.

coast form is rather heavy, being about $36\frac{1}{4}$ pounds, while wood of the Rocky Mountain form weighs about $25\frac{1}{2}$ pounds per cubic foot. Tangentially ("bastard") cut boards have a distinctly pebbled appearance when planed.

In the Rocky Mountain region the wood of this tree is becoming more and more valuable for commercial purposes, which include construction lumber, much used locally, and railway ties. It is also used for corral poles, house logs, and fuel. In the Pacific region it is used principally for these latter purposes.

OCCURRENCE AND HABITS.

In the Rockies *Pinus contorta* occurs on high plateaus and benches in the vicinity of streams, mountain meadows, and lakes, on broad ridges, and on long gentle slopes and bottoms of stream-watered basins at elevations between 7,000 and 11,500 (Map No. 13). North and east slopes are more favorable than west slopes, while south slopes, except in sheltered coves, are least favorable for the growth of this pine. It avoids limestone, but is adapted to dry gravelly soils, seeming to prefer sandy moist ones of gentle slopes, depressions, and plateaus, where the largest growth occurs. Stunted forms grow persistently, however, in crevices of solid rock. It forms extensive pure forests, particularly about meadows; on higher, rocky, rough ground it is sometimes associated with Engelmann spruce, aspen, Douglas fir, and alpine fir.

The lodgepole pine is very intolerant of shade, especially when young, but is able to maintain itself for a long time (from 20 to 50 or more years, or for a longer period) in very dense stands, after which, if wholly relieved from overhead shade, it recovers and grows rapidly. It grows best, however, in full enjoyment of light. Even-aged, dense stands with full top light, such as commonly follow complete destruction of the preceding growth by fire, may thrive for 50 or 60 years with little natural thinning out. But the prompt natural thinning out of overtopped trees at earlier stages in uneven-aged stands is proof that this pine is unable to endure longer continued shade.

This species is usually a prolific annual seeder, bearing large numbers of cones. The seed has a high rate of germination and persistent vitality. Fertile seeds are often borne by trees only from 6 to 10 years of age when growing in the open. In crowded stands cones are borne by trees from 15 to 20 years old. The small light seed is widely disseminated by wind, sometimes being carried 200 yards from the mother trees. Squirrels and birds destroy great numbers of the seeds, but the effect on reproduction appears to be inappreciable. Extension by natural seeding on unburned areas is ordinarily slow,

scant, and uneven; but reproduction on burned-over lands is, with aid of fire (which opens the cones), exceedingly thick and even. Full light and exposed mineral soil are requisites of good reproduction. This favorable condition of the soil is produced by fire, which, when it does not consume the cones, leaves them open or in condition to open and release their seeds.

LONGEVITY.

Lodgepole pine attains an age of from 100 to 175 years, but doubtless it is capable of reaching from 200 to possibly 300 years, if protected from fire, to which it quickly succumbs on account of its thin bark. Few stands have in the past attained an age of over 60 years before being killed by forest fires.

JACK PINE.

Pinus banksiana Lambert.

COMMON NAME AND EARLY HISTORY.

Pinus banksiana does not occur within our Rocky Mountain region, but it enters the Canadian territory immediately north of this region (map No. 14) and it is included here in order to present an account of all the pines in the Rocky Mountain region irrespective of national boundaries.

Jack pine is best known to the public as a tree of southeastern Canadian provinces and of our Great Lakes country, where it is variously called jack pine, scrub pine, black jack pine, gray pine, black pine, Banksian pine, and Hudson Bay pine. The name jack pine is, however, widely used and perhaps the most appropriate.

There appears to be no authentic record of when jack pine was first discovered. It must have been well known to the French explorers and settlers of eastern Canada at least as early as the sixteenth century. Strangely enough the first record of its existence is based on trees cultivated in England,¹ where the species is believed to have been planted prior to 1735. By whom and from what part of its range in this country the seeds or plants were sent to England is unknown. It seems likely, however, that seeds were sent from eastern Canada. The first technical name, *Pinus sylvestris*, δ *divaricata* Aiton, given to this tree was published in 1789 by William Aiton, a Scottish botanist and gardener, who based his brief description of it on trees growing in the Royal Botanical Garden at Kew, England, of which he was then director. Correctly speaking, the logical name for this pine should be *Pinus divaricata* (Ait.) Du Mont de Courset, which is based on this early one of Aiton. But

¹ Loudon, Arb. et Frut. Brit., iv, 2192. 1838.

in accordance with the international rules of nomenclature adopted at Vienna, Austria, in 1905, *Pinus banksiana* of Lambert (1803) is the proper name for this pine. Fortunately, this is the technical name under which jack pine was known to botanists from 1803 to 1892, *Pinus divaricata* having been revived in this country at the latter date and maintained until about 1905. Three other technical names, now reduced to synonymy, were also added during a botanical history extending over a century and a quarter.¹

DISTINGUISHING CHARACTERISTICS.

Jack pine varies in height from a stunted shrubby form only a few feet high to straight well-formed trees from 25 to 60 feet in height and from 8 to 20 inches in diameter; occasional trees reach a height of from 75 to 90 feet and a diameter of about 2 feet. Commonly, however, it is from 25 to 30 feet high and about a foot in diameter. The trunks are clear of branches for one-third or one-half the total height; in very dense stands longer clear trunks are common. Young trees are rather densely clothed down to the ground with noticeably slender branches, which, as a rule, trend sharply upward, forming a pointed oval-shaped crown, which is relatively narrower in a dense stand than in an open one. As the trees grow older, the crown becomes open because the longer, middle-crown and lower-crown branches spread widely or curve downward, and sometimes upward at their ends. The branches are strong and the twigs are notably tough and flexible. Twigs of a season's growth are smooth and light yellowish green, which changes to a deep reddish or purplish brown by the second season; the scaly terminal buds, three-sixteenths to one-fourth of an inch long and about one-eighth of an inch in diameter, are a dark cinnamon-brown. The thinnish dull red-brown bark of mature trunks is narrowly ridged and furrowed, the main irregular ridges being connected by smaller lateral ones.

Compared with its frequent associates, the Norway pine and white pine, this species has strikingly thin foliage, which is due to its short distantly-set leaves. Fully matured leaves are a deep grayish green,

¹ There is no definite record of when *Pinus banksiana* was first introduced into cultivation in England, but it is believed to have been planted there some time prior to 1735. The few trees now growing there, some of which were planted as early as 1839 to 1850, had in 1909 attained heights of from 35 to 40 feet (fide Elwes and Henry, op. cit., 1112). Many trees planted in England during these early years have gradually disappeared, which, in the opinion of Elwes and Henry, indicates that the species is not well adapted to the climate there. It has been extensively planted in Germany by the Government, and to some extent also in Russia, where the trees made remarkably rapid growth during youth. As might be expected, however, this species gives little or no promise for the production of useful timber, its greatest usefulness being to form a tree cover on exceedingly poor sandy and gravelly land where good timber trees will not grow. In the United States, jack pine is one of the few conifers that has been successfully established in the sand-hill region of western Nebraska, where the conditions for tree growth are exceedingly unfavorable.

and those produced each year remain on the branches until about the third summer; in some instances, however, many of them die and fall from the trees during the second season. They are usually curved, and are borne in bundles of two (Pl. XXVIII, *a, b*). In length they vary from about seven-eighths of an inch to nearly $1\frac{1}{2}$ inches, but commonly they are about an inch long. The edges of the leaves bear minute and widely-separated teeth (serratures). A slightly magnified cross section of the leaf shows, as a rule, two resin ducts, one in each angle of the section (edge of leaf); occasional leaves appear to be without resin ducts.

The characteristically one-sided cones (Pl. XXVIII, *b, c*) are fully mature by September of the second season, and two, three, or four of them may be borne in one cluster. They vary in length from $1\frac{1}{4}$ to about 2 inches and from one-half to nearly 1 inch in diameter at the thickest place. Early in autumn they are a greenish to a deep purple, but later they turn to a light clay-brown, the ends of the closely pressed cone scales being shiny. During the first season the scales of young cones bear delicate curved prickles, which, however, usually disappear or are very inconspicuous by the time the cones are ripe. A characteristic habit of the cones of this pine is to remain attached to the trees for from 12 to 25 years or more. The cones are peculiar also in that they open irregularly and liberate only a few of their seeds at a time and then usually only after the cones have remained closed for two or three years. The triangular seeds are from one-eighth to three-sixteenths of an inch long and about three thirty-seconds of an inch wide, and are covered with a blackish-brown minutely pebbled membrane, tiny bits of which become detached and show the light yellow-brown shell of the seed beneath. The upper side of the seed is more or less distinctly marked with two grooves. The seed-leaves vary in number from four to five (Pl. XXVIII, *e*; lowermost long leaves).

Jack pine wood is variable in texture and weight from rather soft and light to rather hard and moderately heavy, some grades of the wood being nearly of the same hardness and weight as Norway pine. A cubic foot of dry wood weighs about $29\frac{3}{4}$ pounds. When seasoned it is brittle and weak and decays rapidly in contact with earth. The sapwood is thick and of a uniform pale creamy white, but the heartwood varies in color from a bright, slightly brownish yellow to a light yellow-brown. The wood formed during the first 15 or 20 years, when the tree grows rapidly, is moderately wide-ringed; that formed during the remainder of the tree's life, when diameter growth is very much slower, is narrow-ringed—sometimes exceedingly so. Little is known now regarding the use, if any, of this timber in the far northwestern range of the tree. In the central and eastern parts



PINUS BANKSIANA.

a, Foliage; b, c, clusters of closed cones; d, seedling one month old; e, seedling.

of its range, where formerly this pine was very abundant, the wood was but little used, except locally for fuel, light-traffic ties, and occasionally for rough lumber. In recent years, however, the scarcity and high cost of other northeastern pines has led to extensive commercial use of jack pine lumber wherever the trees are large enough to be milled. Logs as small as 6 inches in diameter are now cut into rough slack-cooperage stock and lumber for packing cases. Heavy "tongue-and-grooved" jack pine planking, used for roofing under a waterproof covering and for various other similar purposes, has been entering our northeastern markets more and more of recent years, but usually under an assumed name. The so-called "Hudson Bay pine," purporting to come from a far northern source, is in some instances jack pine. Clear grades of jack pine are so similar in appearance and working qualities to Norway pine that they could probably pass for Norway pine. For the most part, however, jack pine produces a low-class knotty lumber unfit for the better uses to which Norway pine is put.

OCCURRENCE AND HABITS.

Jack pine is essentially a tree of barren sandy or rocky land throughout its wide range (Map No. 14). It occurs also, however, in moist soils of good quality, which, if well drained, produce the largest trees. The vertical range of jack pine is between about 100 and 1,200 feet above sea level. For the most part it forms either small scattered patches or extensive bodies of pure growth. In its eastern range *Pinus banksiana* is associated more or less with white pine, and to some extent also with Norway pine. The mingling of these species occurs chiefly when the jack pine begins to decline, the red and white pines later generally crowding it out. Jack pine is decidedly intolerant of shade at every period of its life except during the first year or two of seedling growth, when it bears light shade, but with some loss of vigor.

Pinus banksiana is an abundant seeder, some seed being borne practically every year, but specially heavy seed production occurs at intervals of about 2 or 3 years. Trees in an open stand often begin to bear cones when they are only a few feet high (10 to 12 years old);¹ trees in a dense stand begin to bear when about 25 years old. The seed has a very high rate of germination (from 60 to 80 per cent) and persistent vitality. Reproduction is usually scattered, owing doubtless to the irregular and tardy opening of the cones, but the precocious seed bearing results in gradual and constant extensions and the filling out of openings in thin stands of this tree.

¹ Near relatives of the jack pine, *Pinus contorta*, *P. virginiana*, and *P. clausa*, have the similar habit of producing cones at a very early age.

Moreover, the habit this tree has of long retaining its cones in a closed state enables the species to perpetuate itself even after severe fires have killed the mother trees, because, if not too badly burned, many of the charred cones then open and liberate their seed. Vast areas in the central and eastern parts of its range once heavily stocked with *Pinus strobus* and *P. resinosa* are now re-covered with jack pine, which is often the only growth on these barrens.

LONGEVITY.

Jack pine is comparatively short-lived, the largest trees probably not exceeding from 125 to 150 years of age. As a rule, however, the age of such trees can not be determined accurately, because they are decayed at the heart. The oldest sound trees ordinarily cut rarely exceed 110 years in age. Trees from 6 to 15 inches in diameter grown in an open stand are from 25 to 85 years old, while 6-inch trees grown in a dense stand are from 70 to 75 years old.

KEY TO SPECIES.

- Leaves borne singly (or some of them 2 in a bundle)----- *Pinus monophylla*
- Leaves borne in bundles of 2:
 - Cones armed with delicate prickles----- *Pinus contorta*
 - Cones without prickles—
 - Cone scales widely open after the cones are ripe----- *Pinus edulis*
 - Cone scales mostly closed, or only part of them open, after the cones are ripe----- *Pinus banksiana*
- Leaves borne in bundles chiefly of 3 (sometimes in bundles of 2, 4, or 5):
 - With a prominent basal sheath—
 - Cone scales armed with stout prickles—
 - Leaves mostly from about 4 to 7 inches long----- *Pinus ponderosa*
 - Leaves mostly from about 8 to 15 inches long----- *Pinus apachea*
 - Without a basal sheath:
 - Cones borne on long, slender stems----- *Pinus chihuahuana*
 - Cones borne on very short stems----- *Pinus cembroides*
- Leaves borne in bundles of 5 and cones with prickles:
 - Cone scales armed with long, delicate prickles----- *Pinus aristata*
 - Cone scales armed with short stout prickles----- *Pinus arizonica*
- Leaves borne in bundles of 5 and cones without prickles:
 - Cones opening at maturity and shedding their seeds—
 - Cone scales strongly reflexed at the tips----- *Pinus strobiformis*
 - Cone scales mostly not reflexed at their tips—
 - Seeds with long, well-defined wings----- *Pinus monticola*
 - Seeds with very short rudimentary wings----- *Pinus flexilis*
 - Cones remaining closed at maturity----- *Pinus albicaulis*

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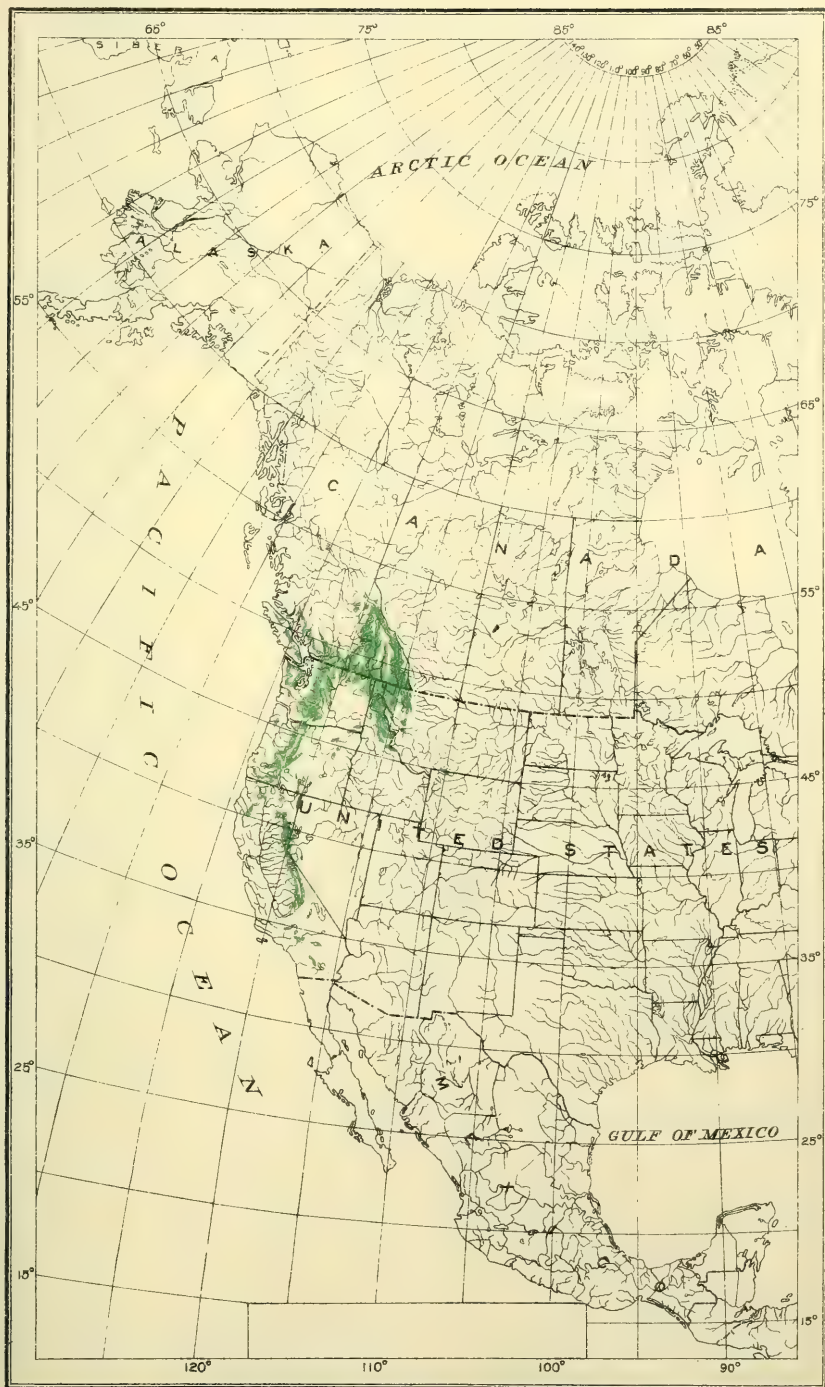
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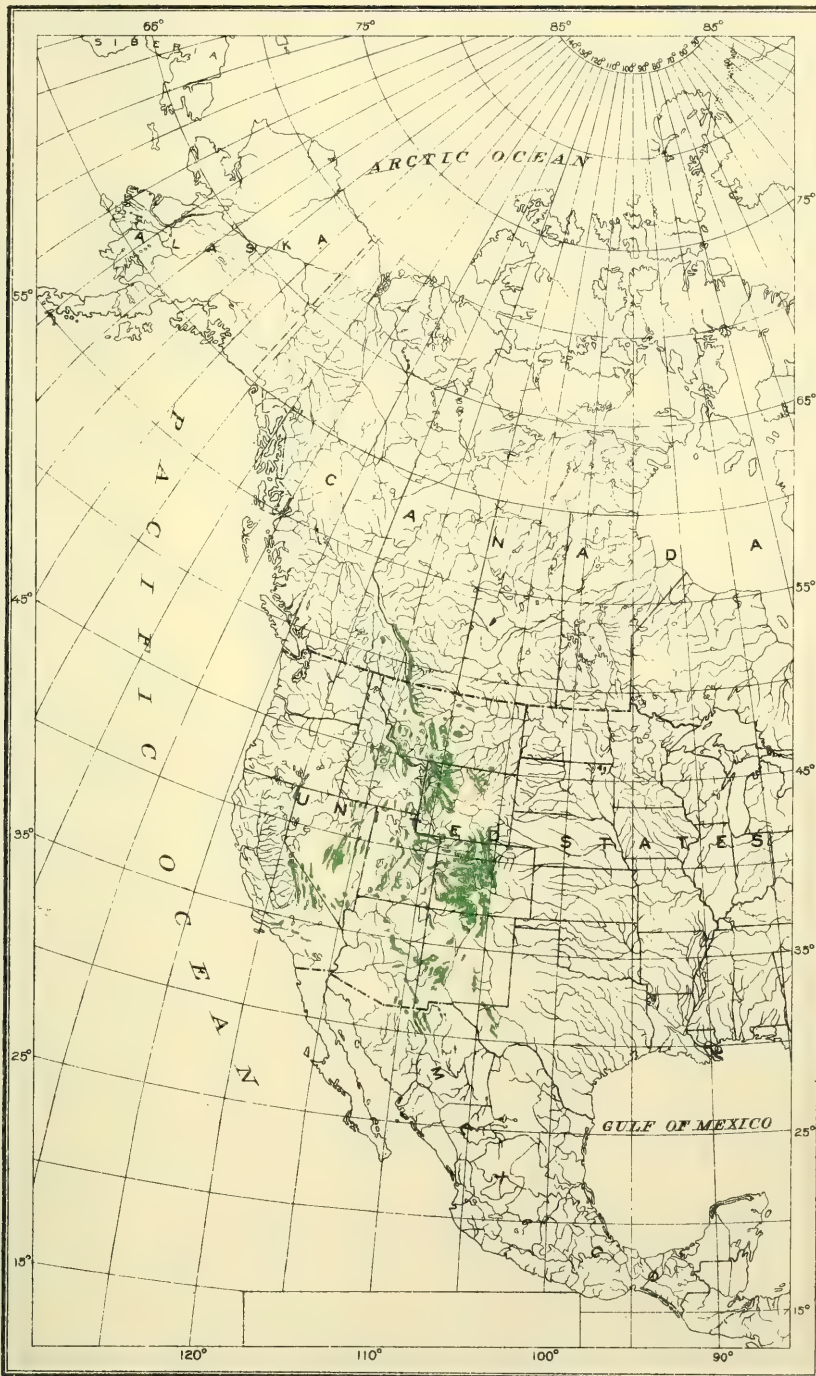
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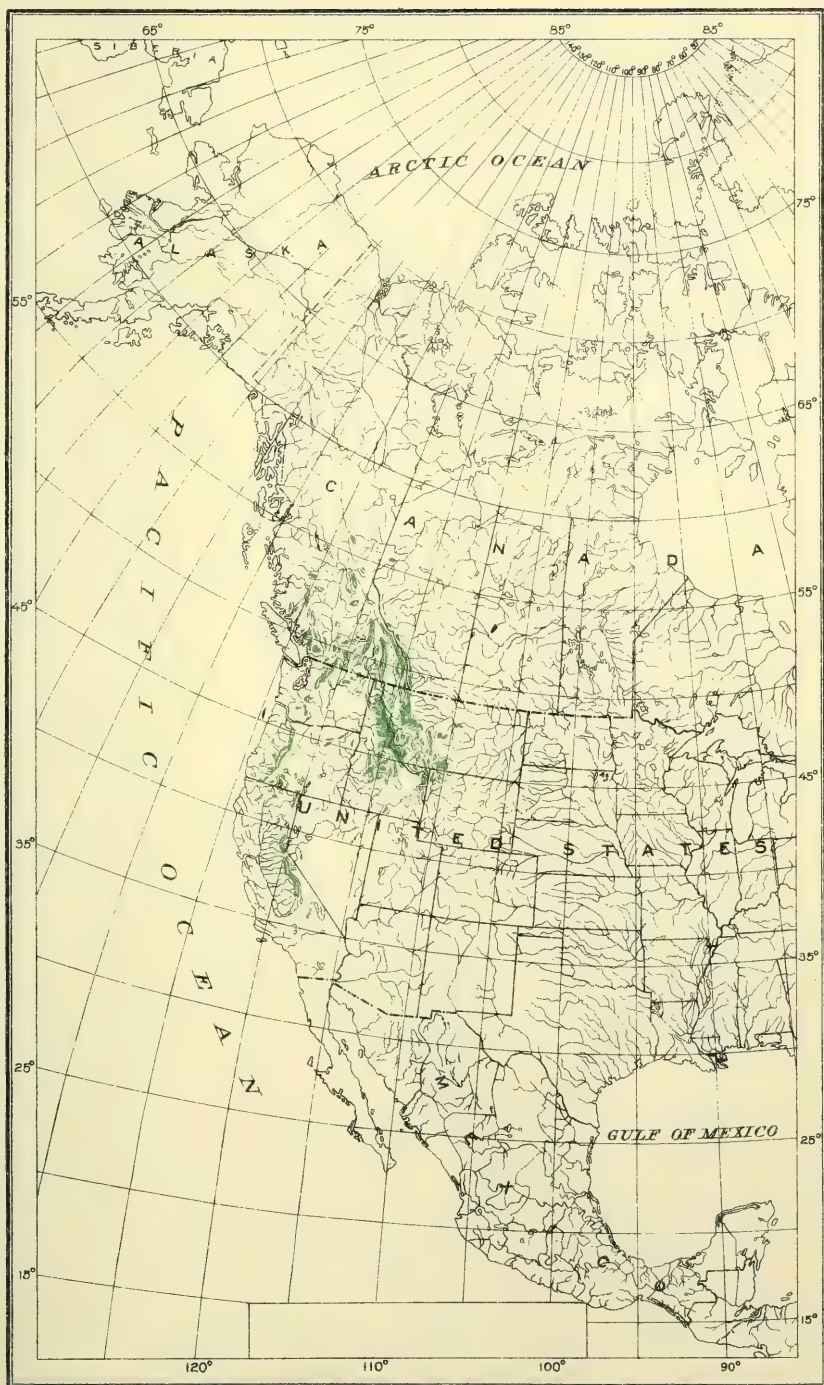
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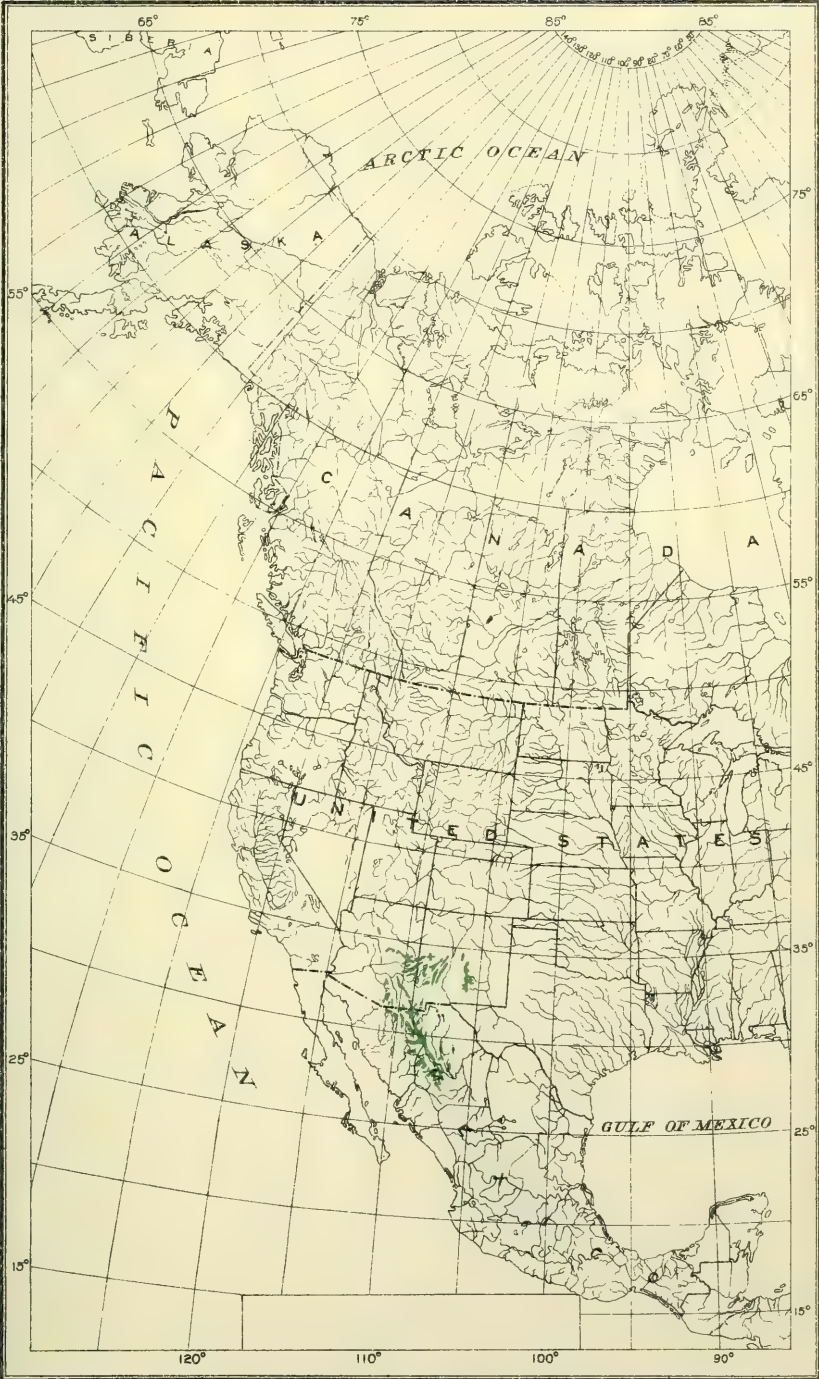
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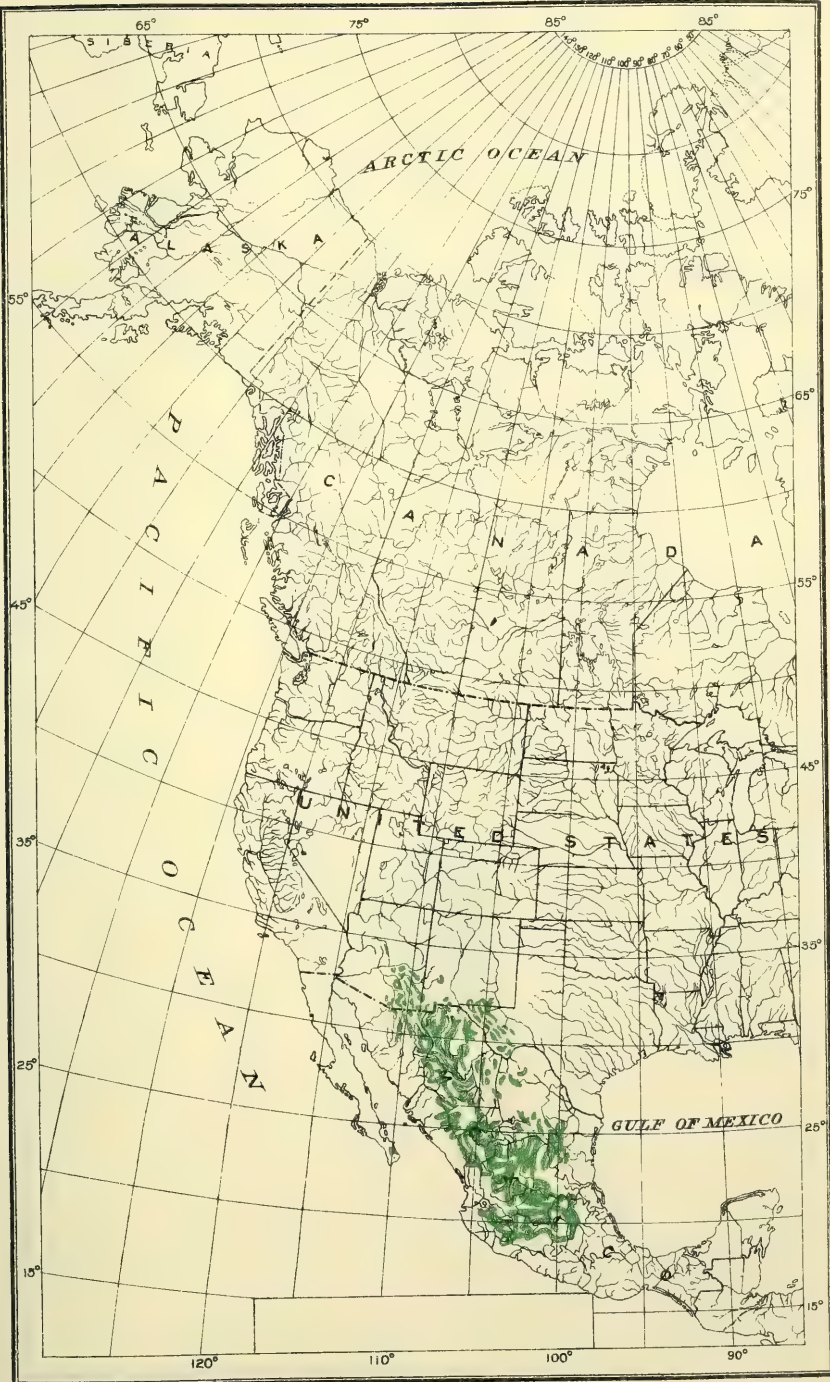
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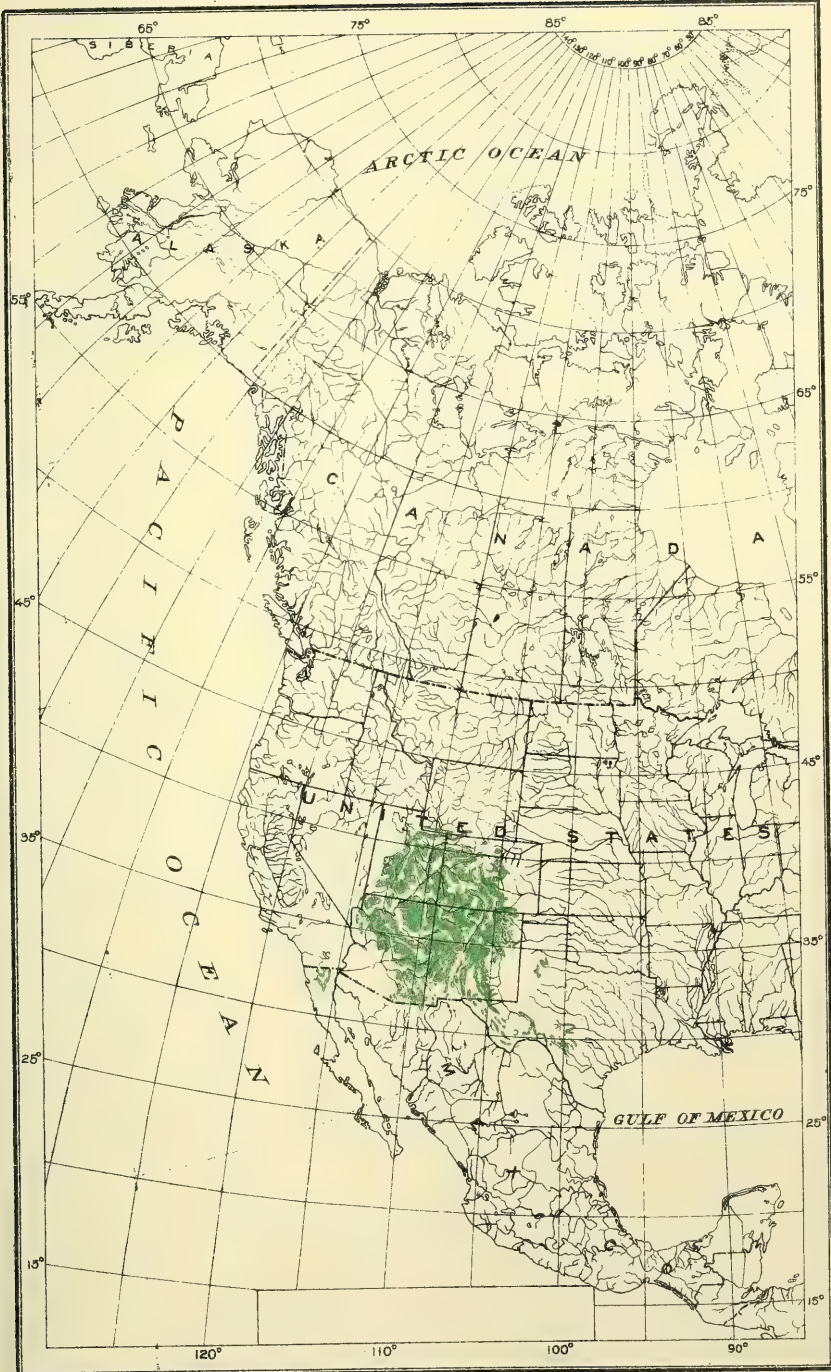
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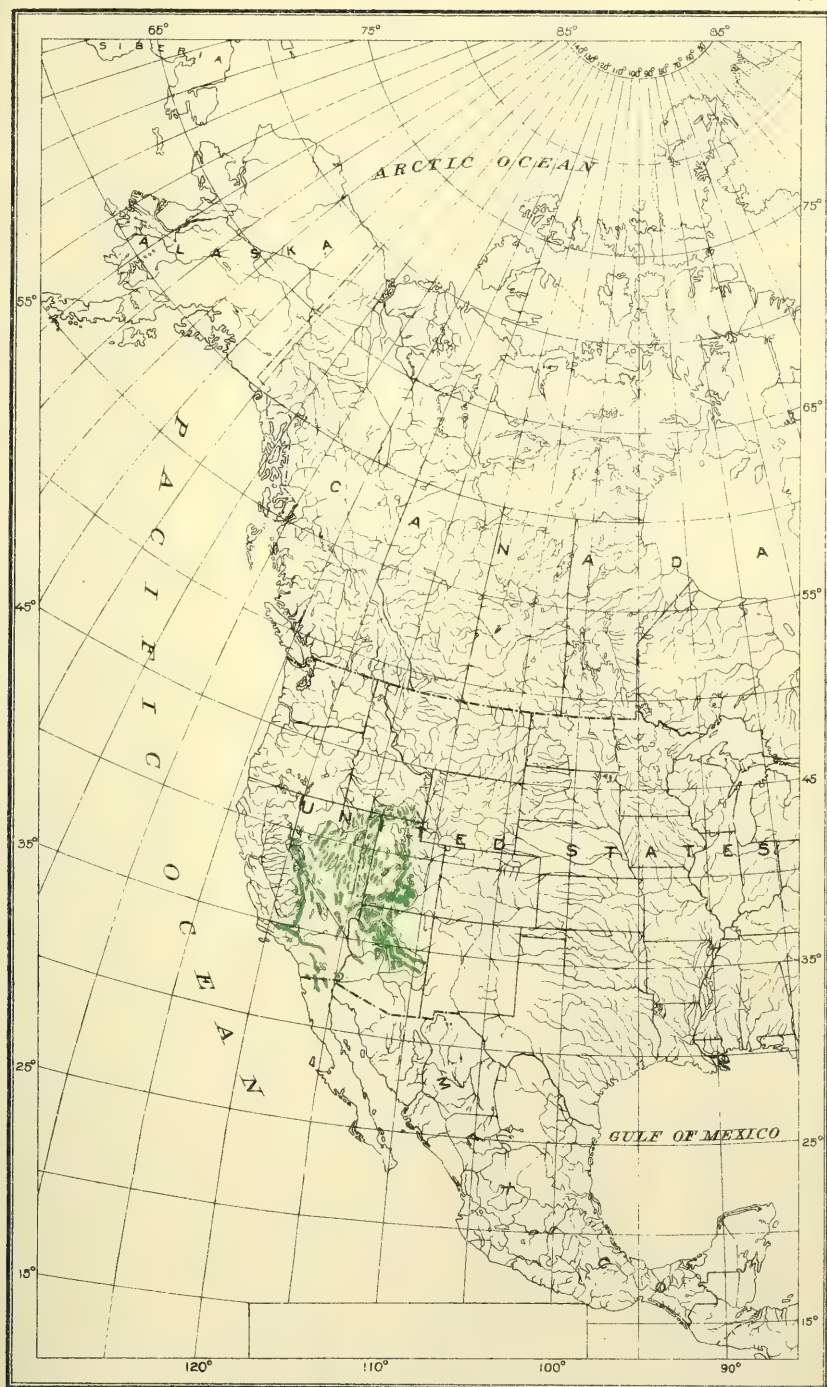
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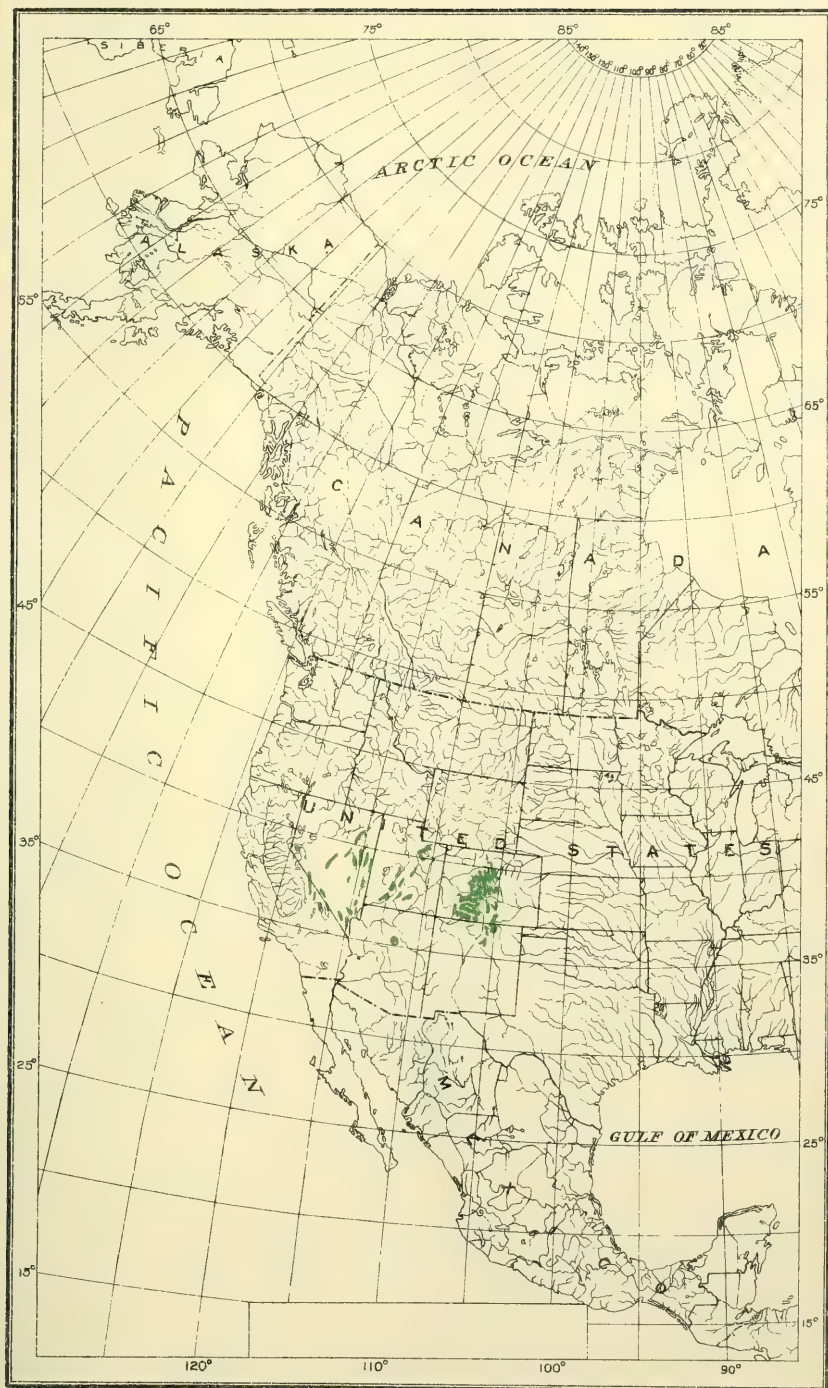


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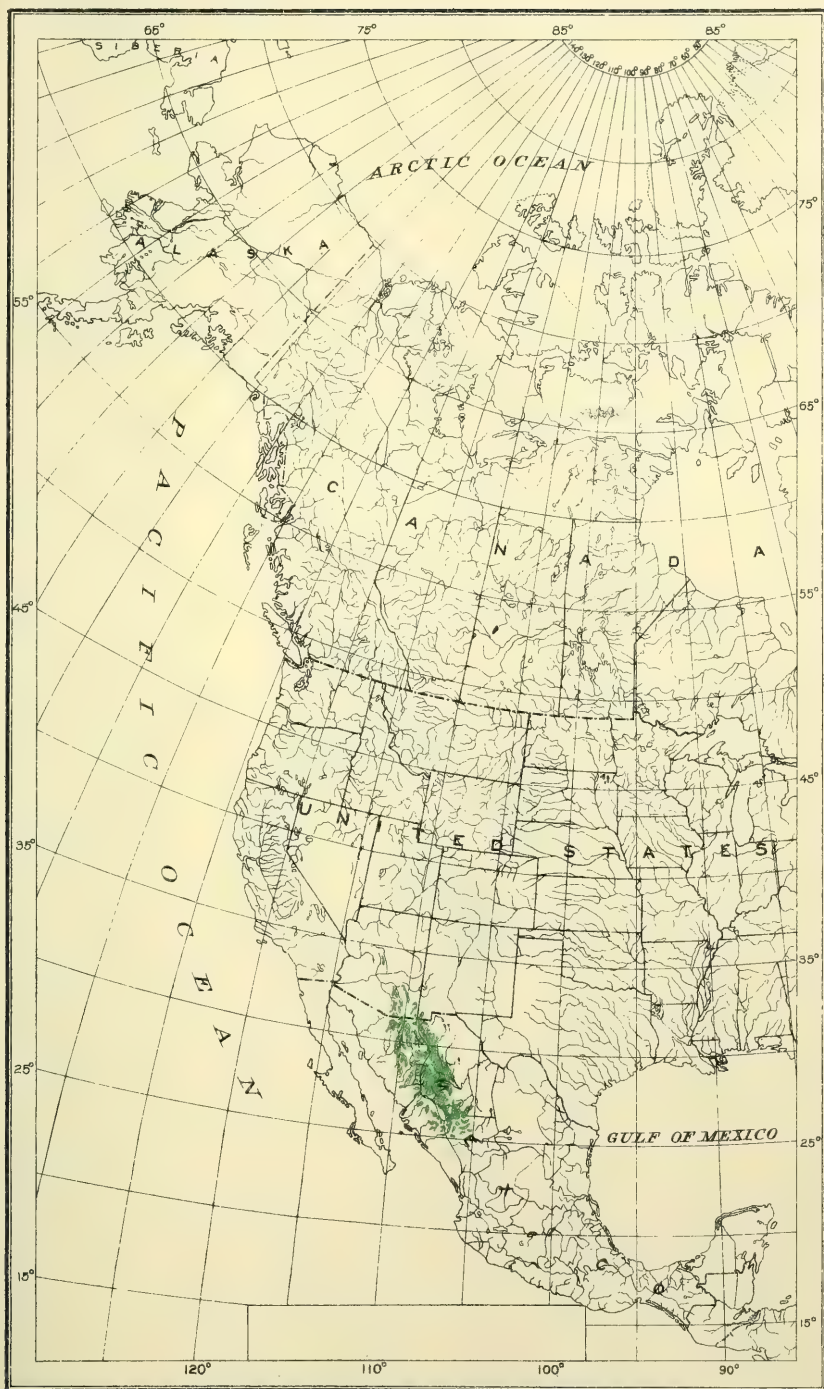


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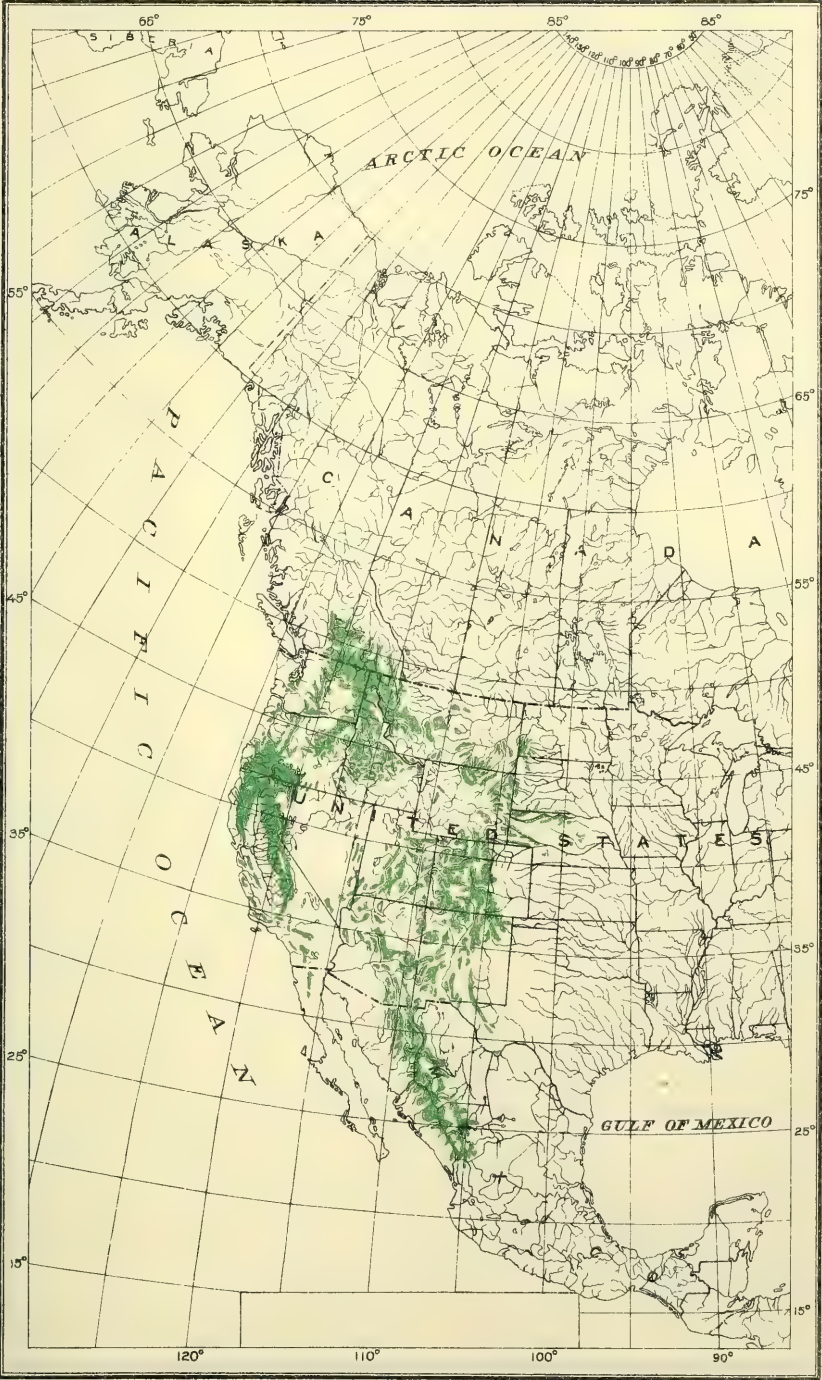




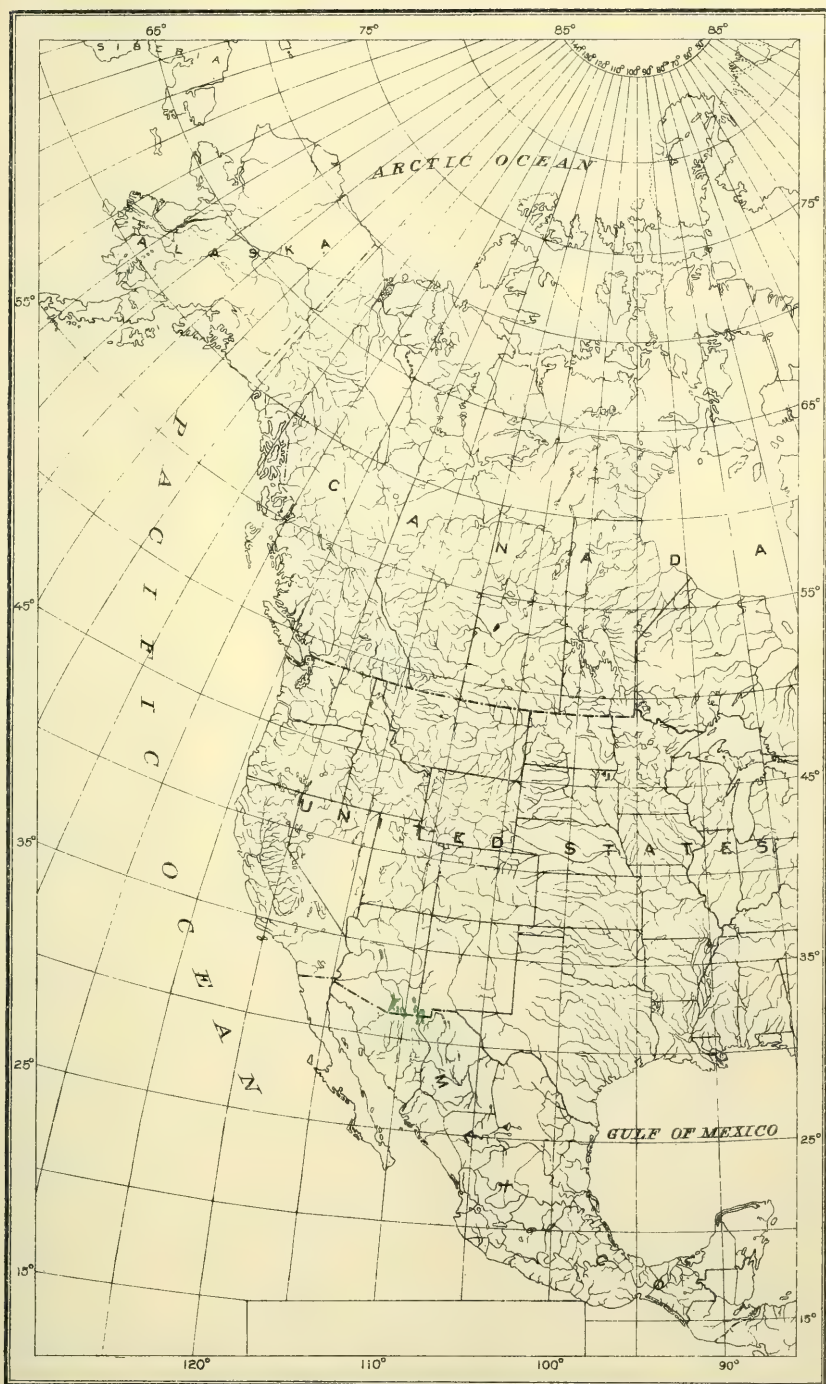
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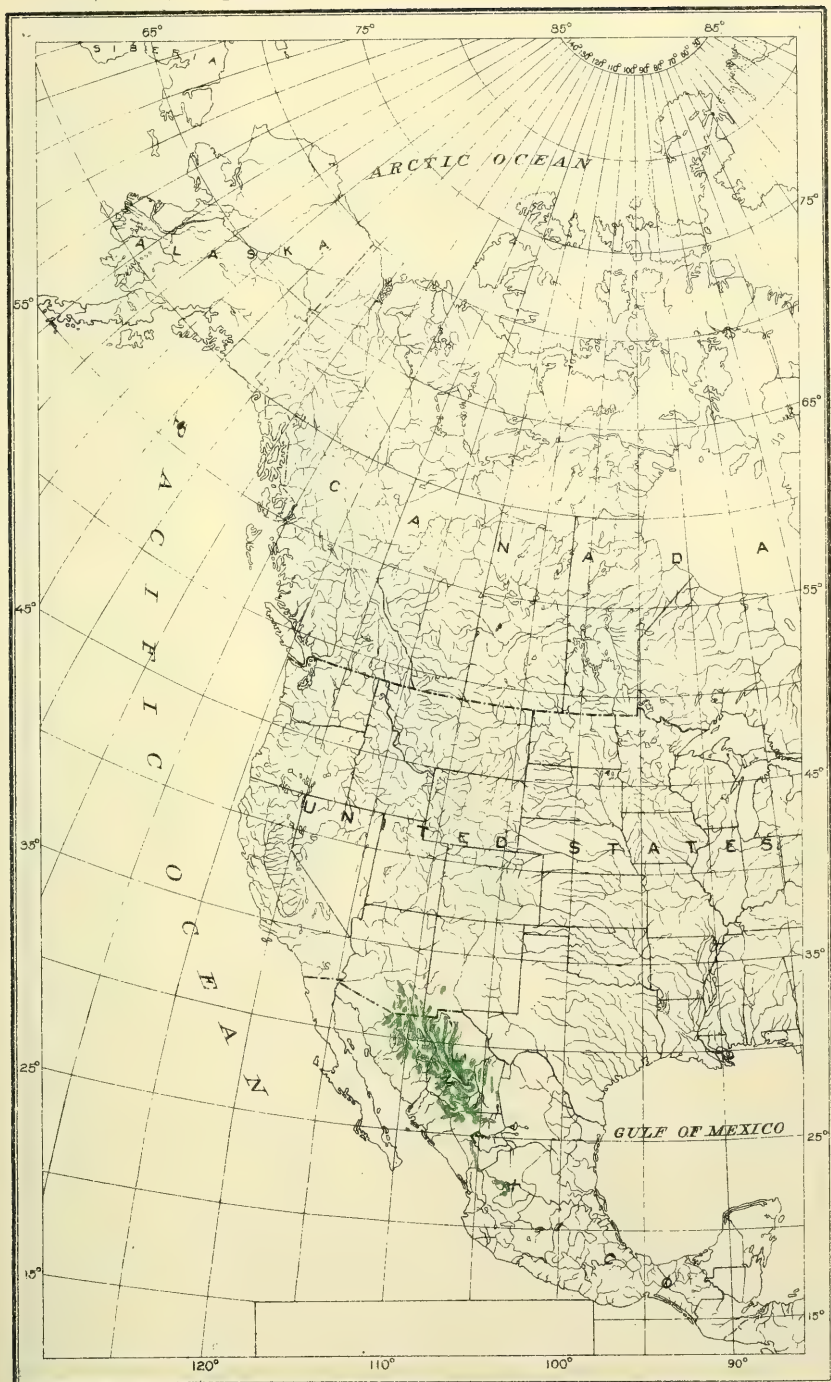


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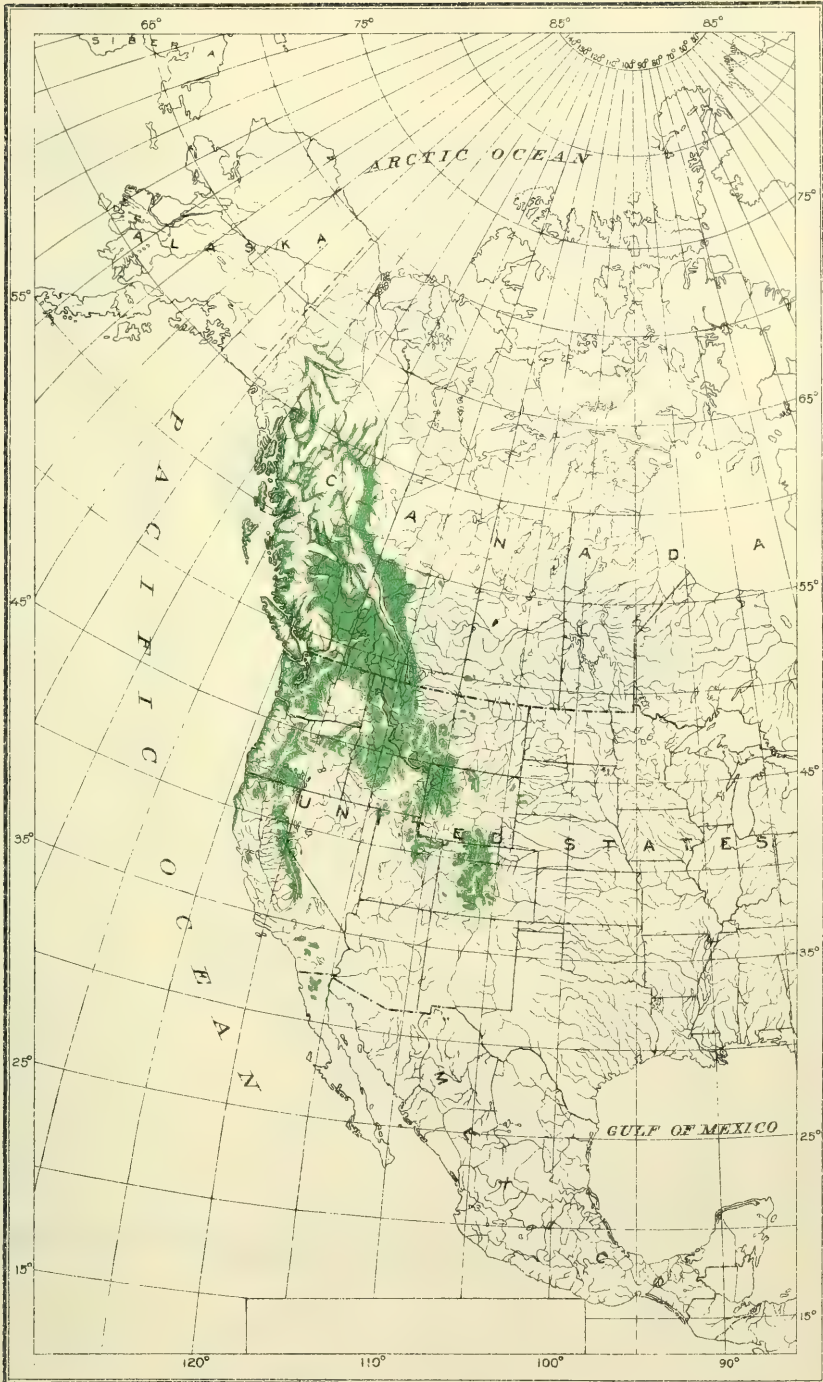


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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 461

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.

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THE IDENTIFICATION OF GRASSES BY THEIR
VEGETATIVE CHARACTERS.

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Agronomist in Pasture Investigations, Forage-Crop Investigations.

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INTRODUCTION.

It is often desirable to identify grasses by their vegetative characters. The usual botanical classifications based on the structure of the flowering parts are not useful for this purpose. Any mention of the leaves which may be included in botanical descriptions is usually for the purpose of confirming an identification. In lawns and pastures the best grasses are seldom allowed to reach the flowering stage, and some grasses change so materially in appearance as they reach maturity that it is difficult to see a resemblance to the young plants in those that have headed.

There have been previous attempts to work out keys for identifying young grasses, especially those of McAlpine,¹ of Ward,² and of Percival.³ Stebler and Schröter⁴ have described and illustrated fully the vegetative characters of the most common hay and pasture

¹ McAlpine, A. N. How to know grasses by the leaves. *In* Standard Cyclopedia of Modern Agriculture, v. 6, p. 153. 1890.

² Ward, H. M. Grasses. 190 p., illus. Cambridge, 1901.

³ Percival, John. Agricultural botany. 798 p., illus. London, 1900.

⁴ Stebler, F. G., and Schröter, Carl. The best forage plants. 3 v. in 1, illus., pl. London, 1889.

grasses. Lewton-Brain¹ has described the leaf anatomy of many British grasses.

The general plan of classification used in this bulletin follows somewhat that of Percival, but it is enlarged to include about three times the number of grasses described by him.

WHAT IS MEANT BY THE TERM "GRASS."

In this discussion the term "grass" is restricted entirely to those plants which botanists group in the family Gramineæ or Poaceæ and does not include the clovers and some other forage plants which are often classed agriculturally under the term "grass." The true grasses are recognizable by the following characters: Stems jointed, usually hollow; leaves in two ranks on opposite sides of the stem, each consisting of two parts, the **blade**, usually narrow and elongated, and the **sheath**, or basal portion, tubular and enwrapping the stem, its margins free or rarely grown together; leaf nerves parallel; at the junction of the sheath and blade a small membranous appendage, the **ligule**, which is sometimes wanting.

The plants which are most likely to be mistaken for grasses are the sedges (fig. 1), characterized by 3-ranked leaves on a solid, usually 3-angled stem, and the rushes (fig. 2), distinguished by solid stems, tubelike closed sheaths, and cylindrical or straplike leaves, neither folded nor rolled in the bud, and without ligules.

CHARACTERISTICS OF GRASSES BEFORE THE BLOOMING STAGE.

Grasses, like other flowering plants, may be considered as made up of roots, stems, leaves, and flowering parts. The natural classification of grasses is based mainly on the flowers and fruits, but the other organs show much variation in structure; indeed, sufficient to identify most grasses from their vegetative parts alone.

Roots.—The true roots of grasses are very slender and often much branched. They vary less than other organs, however, so that it is rarely possible to identify a grass from its roots alone, at least from the gross structure.

Stems.—Apart from the erect stems of grasses, which are usually flower bearing, many species have stems of a different sort. In some cases these are creeping, leaf bearing, and often rooting at the joints. Such stems are termed **stolons**. Many grasses have underground stems. These are jointed, bear scalelike reduced leaf sheaths, and are usually horizontal and coarser than roots. Such underground stems are termed **rootstocks** or **rhizomes**.

¹ Lewton-Brain, Lawrence. On the anatomy of the leaves of British grasses. *In Trans. Linn. Soc., London, s. 2, Bot., v. 6, pt. 7, p. 315-359, pl. 36-40. 1904.*

Leaves (fig. 3).—A grass leaf consists of two principal parts, the sheath or tubular basal portion which incloses the stem, and the **blade**, nearly always long, narrow, and most commonly flat. The sheaths are usually cylindrical in form, but in some grasses they are laterally compressed, forming a keel at the back, in which case they are described as compressed. In some grasses the nerves of the sheaths are prominent, in others scarcely noticeable. A few grasses have distinctively colored sheaths, the coloration being especially noticeable in the portion below ground. At the junction of the sheath and the blade are structures that are very useful in identifying grasses not in blossom. On the inside of the sheath is a small



FIG. 1.—A common sedge.

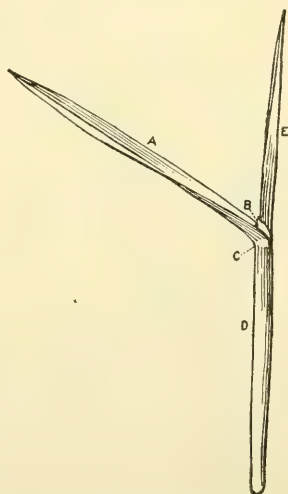
FIG. 2.—A *Juncus*.

FIG. 3.—Different parts of a grass: A, Blade; B, ligule; C, collar; D, sheath; E, shoot or bud leaf.

organ, the **ligule**, apparently a continuation of the lining of the sheath and usually very thin in texture. It usually consists of a thin, semitransparent membrane, but sometimes it is a mere fringe of hairs, and only in rare cases is it wholly absent. The ligules of some grasses are wider than the sheaths and continuous with the hyaline margins. Owing to its wide variation in form, the ligule is one of the most dependable of characters for identification. Several special terms are necessary to describe these forms: **Entire**, when there are no notches or indentations along the margin; **lacerate**, when the margin is much cut; **truncate**, when the apex is apparently cut off squarely; **acute**, when the apex terminates in a sharp point; and **ciliate**, when the margin is fringed with hairs. Other terms, such as "toothed along the margins," or "hairy on the back," are self-explanatory.

The **collar** is a narrow band marking the place where the blade and the sheath join. It is often scarcely differentiated, but usually has a different color from either the blade or the sheath. In some cases the collar is a continuous band extending from one margin of the leaf to the other, but in others it is divided into two parts by the midnerve. The margins of the collar in some grasses are wavy, in others straight; some are hairy, others entirely glabrous or hairless. In some grasses one side of the collar is higher than the other, giving it a spiral appearance.

The **auricles** are earlike or clawlike appendages projecting from the collar or the angles at the top of the sheaths in a few grasses. They may be small or large, hairy or free from hairs. Often they clasp the stems more or less, especially when young, but as they become older and dried they may turn away from the stem. Only the narrow clawlike auricles are considered in the analytical key.

The flowering parts are not used in this classification. If the grass has reached the blooming stage it can be more easily identified by using one of the many books on the subject.

The word **glabrous** is used to mean free from hairs.

HOW TO USE THE KEY IN IDENTIFYING GRASSES.

The analytical key (pp. 6-9) is composed of pairs of opposing statements. The first statement of each pair is designated by a letter, A, B, C, etc.; the second one has the same letter as the first, but repeated, as AA, BB, CC, etc. The statements constituting each pair may be close together, as "A. Auricles narrow and clawlike, clasping the stems more or less," and "AA. Auricles wanting, or at least not narrow and clawlike," or they may be separated as "B. Collar hairy," and "BB. Collar not hairy." If a specimen does not agree with the first statement, all intervening headings should be passed over at once until the corresponding second statement which does apply is reached.

One of the best ways to learn to use this key is to get specimens of young grasses and endeavor to trace them. Take, for example, orchard grass. The first thing that must be done is to determine whether the leaf is folded (fig. 4, *A*) or rolled (**convolute**; fig. 4, *B* and *C*) in the bud. This is best done by cutting across the young shoot with a sharp knife and examining it with a lens. Another method of determining this point is to strip off the leaves carefully until the youngest is exposed and then examine with a lens. With the larger grasses it is easy to decide whether the leaves are folded or rolled in the bud, but with the finer sorts, such as the bent grasses or the fescues, it is sometimes difficult. The leaf in the case of orchard grass is folded in the bud, so it will come in Group J. The first line of the key, marked "A," reads "Auricles

narrow and clawlike, clasping the stem more or less." As orchard grass does not have clawlike auricles, pass on to the line "AA," which reads "Auricles wanting, or at least not narrow and clawlike." The next line after "AA," marked "B," reads "Collar hairy." Orchard grass does not have a hairy collar; so, pass over the intervening subjects to line "BB. Collar not hairy." The next line, "C. Sheaths below ground bright yellow," does not apply to this grass; so, pass on to "CC. Sheaths below ground not yellow." The next line, "D. Blades narrow and bristlelike, but with prominent veins on upper surface," does not apply; so, pass on to "DD. Blades flat; nerves not prominent." The next line, "E. Blades broad without white lines along midnerve by transmitted light; tip of blade taper pointed," applies, and here is also given the name of the grass.

The number before the common name of the grass refers to the number given this grass in the general description following the key. As there are several hundred grasses and this key includes but 56,

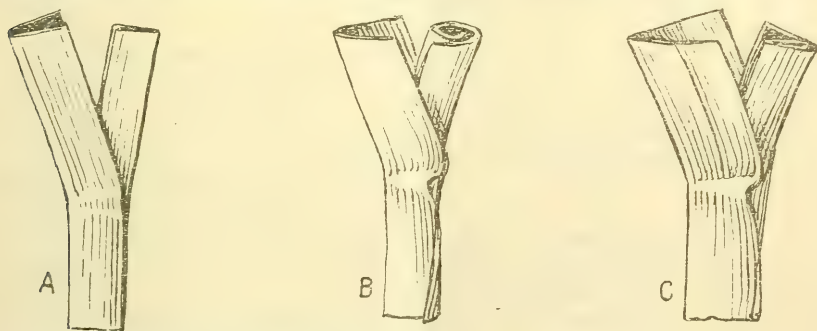


FIG. 4.—Different arrangements of leaves in the buds: A, Folded; B and C, rolled or convolute.

it is readily apparent that some grasses not mentioned here might be traced out in the key and be given wrong names. If a specimen answers all the requirements of the key as a certain grass but does not correspond with the detailed description, it is evidently not included in this bulletin.

While the characters which have been used are the ones that appear to be the most reliable, it is not uncommon to find individual specimens of every species which differ from the majority. For instance, tall oat-grass often has a few hairs on the sheaths. Timothy and a number of other grasses sometimes have pink or violet colored sheaths below ground when grown under certain conditions. It is very important to study several specimens of a species, if possible, before attempting to identify it.

No claim is made that this key is infallible. It has been of much assistance to the writer in identifying the common hay and pasture grasses, and it is hoped that it may serve the same purpose for others.

The small grains, while true grasses, have been placed in a separate group (p. 26), as there is more danger of confusing them with each other than with the other grasses. The grasses studied are all common to the eastern part of the United States, and no attempt has been made to include the distinctively western species.

ANALYTICAL KEY TO GRASS SEEDLINGS.

GROUP I.—Leaves folded in the bud; shoot apparently flattened.

- A. Auricles narrow and clawlike, clasping the stems more or less.
 - 1. Perennial rye-grass (*Lolium perenne*).
- AA. Auricles wanting, or at least not narrow and clawlike.
 - B. Collar hairy.
 - C. Stolons present, creeping.
 - 2. Carpet grass (*Axonopus compressus*).
 - CC. Stolons absent.
 - D. Leaves less than one-fourth inch wide.
 - 3. Poverty grass (*Danthonia spicata*).
 - DD. Leaves one-fourth inch wide.
 - E. Collar divided by the midnerve.
 - 4. Broom sedge (*Andropogon virginicus*).
 - EE. Collar not divided by the midnerve.
 - 5. Yard-grass (*Eleusine indica*).
 - BB. Collar not hairy.
 - C. Sheaths below ground bright yellow.
 - 6. Crested dog's-tail grass (*Cynosurus cristatus*).
 - CC. Sheaths below ground not yellow.
 - D. Blades narrow and bristlelike, but with prominent veins on upper surface.
 - E. Rootstocks wanting; plant growing in a dense tuft.
 - 7. Sheep's fescue (*Festuca ovina*).
 - EE. Rootstocks present; plant creeping, forming an even turf.
 - 8. Red fescue (*Festuca rubra*).
 - DD. Blades flat; nerves not prominent.
 - E. Blades broad without white lines along midnerve by transmitted light; tip of blade taper pointed.
 - 9. Orchard grass (*Dactylis glomerata*).
 - EE. Blades narrow, with a white line on each side of the midnerve, the leaf being held up to the light and examined with a lens; tip of blade abrupt, boat shaped.
 - F. Rootstocks usually wanting.
 - 10. Annual bluegrass (*Poa annua*).
 - FF. Rootstocks present.
 - G. Herbage pale bluish green.
 - 11. Canada bluegrass (*Poa compressa*).
 - GG. Herbage dark green.
 - H. Ligule short, truncate; stems smooth.
 - 12. Kentucky bluegrass (*Poa pratensis*).
 - HH. Ligule long, acute; sheaths rough.
 - 13. Rough-stalked meadow grass (*Poa trivialis*).

GROUP II.—Leaves rolled in the bud; shoot apparently cylindrical.

- A. Auricles narrow and clawlike.
 - B. Sheaths reddish below ground; blades shining beneath.
 - C. Leaf margins smooth.
 - 14. Italian rye-grass (*Lolium multiflorum*).
 - CC. Leaf margins rough.
 - 15. Meadow fescue (*Festuca elatior*).
 - BB. Sheaths not reddish.
 - C. Rootstocks present.
 - 16. Quack-grass (*Agropyron repens*).
 - CC. Rootstocks wanting.
 - D. Hairs on sheaths pointing downward.
 - 17. Virginia wild rye (*Elymus virginicus*).
 - DD. Hairs on sheaths pointing upward.
 - 18. Slender wild rye (*Elymus striatus*).
 - AA. Auricles wanting, or at least not clawlike.
 - B. Sheaths not laterally compressed.
 - C. Collar or sheath hairy.
 - D. Sheaths not hairy.
 - 19. Sweet vernal grass (*Anthoxanthum odoratum*).
 - DD. Sheaths hairy.
 - E. Collar not hairy.
 - 20. Soft chess (*Bromus hordeaceus*).
- (NOTE.—Tall oat-grass sometimes has hairy sheaths; it would then be placed here.)
- EE. Collar hairy.
 - F. Rootstocks present.
 - 21. Switch-grass (*Panicum virgatum*).
 - FF. Rootstocks not present.
 - 22. Downy brome-grass (*Bromus tectorum*).
 - CC. Collar and sheaths not hairy.
 - D. Rootstocks or stolons present.
 - E. Sheaths dark violet below ground.
 - 23. Meadow foxtail (*Alopecurus pratensis*).
 - EE. Sheaths pale below ground.
 - F. Rootstocks more than one-eighth inch in diameter.
 - 24. Reed canary grass (*Phalaris arundinacea*).
 - FF. Rootstocks less than one-eighth inch in diameter.
 - G. Leaves one-fourth inch wide.
 - 25. Redtop (*Agrostis alba*).
 - GG. Leaves one-eighth inch wide.
 - 26. Creeping bent (*Agrostis stolonifera*).
 - DD. Rootstocks and stolons not present.
 - E. Sheaths white, with pink nerves.
 - 27. Chess (*Bromus secalinus*).
 - EE. Sheaths without pink nerves.
 - F. Margins of blades rough, retrorsely so near base.
 - 28. Timothy (*Phleum pratense*).
 - FF. Margins of blades smooth.
 - G. Stems without bulbs below ground.
 - 29. Tall oat-grass (*Arrhenatherum elatius*).
 - GG. Stems with bulbs below ground.
 - 30. Bulbous oat-grass (*Arrhenatherum elatius bulbosum*).

BB. Sheaths laterally compressed.

C. Collar and sheath not hairy.

D. Rootstocks or stolons present.

E. Creeping stems (rootstocks) more than one-eighth inch in diameter.

31. Johnson grass (*Andropogon halepensis*).

EE. Creeping stems (stolons) less than one-eighth inch in diameter.

32. Nimble Will (*Muhlenbergia schreberi*).

DD. Rootstocks and stolons not present.

E. Ligule wanting.

33. Barnyard grass (*Echinochloa crus-galli*).

EE. Ligule present.

F. Ligule membranous.

34. Sudan grass (*Andropogon sorghum sudanensis*).

FF. Ligule a fringe of hairs.

G. Blades hairy above.

35. Yellow foxtail (*Chaetochloa lutescens*).

GG. Blades not hairy.

36. Spreading witch-grass (*Panicum dichotomiflorum*).

CC. Collar or sheath hairy (either or both).

D. Ligule membranous.

E. Sheaths white, with pink nerves.

F. Ligule entire, hairy on the back.

37. Rescue grass (*Bromus unioloides*).

FF. Ligule toothed on margin, not hairy on the back.

38. Velvet grass (*Holcus lanatus*).

EE. Sheaths pale, without pink nerves.

F. Stolons present.

G. Sheaths hairy.

39. Crab-grass (*Syntherisma sanguinalis*).

GG. Sheaths not hairy.

40. Small crab-grass (*Syntherisma ischaemum*).

FF. Stolons not present.

G. Habit of growth low and decumbent at the base.

41. Field paspalum (*Paspalum laeve*).

GG. Habit of growth upright.

42. Smooth paspalum (*Paspalum dilatatum*).

DD. Ligule a fringe of hairs.

E. Rootstocks present.

43. Bermuda grass (*Capriola dactylon*).

EE. Rootstocks not present.

F. Sheaths hairy.

G. Collar hairy on the back.

44. False redtop (*Tridens flavus*).

GG. Collar not hairy on the back.

45. Green foxtail (*Chaetochloa viridis*).

FF. Sheaths not hairy.

G. Collar hairy on the back.

46. Flat-stemmed panic (*Panicum anceps*).

GG. Collar not hairy on the back.

H. Leaves one-sixteenth inch wide.

47. Slender meadow grass (*Eragrostis pilosa*).

HH. Leaves one-eighth inch wide.

48. Stink-grass (*Eragrostis cilianensis*).

DETAILED DESCRIPTIONS OF FORTY-EIGHT SEEDLING GRASSES.

1. Perennial rye-grass (*Lolium perenne*; fig. 5).

A perennial, glabrous, dark-green, tufted grass; leaves folded in the bud; collar narrow, glabrous; auricles small, slender, clawlike; ligule membranous, short, obtuse, toothed near the tip; sheaths reddish below ground, smooth; blades flat, prominently nerved above, glossy and smooth beneath, long-linear, about one-eighth inch or more wide, sharp pointed.

This grass makes considerable winter growth in the Southern States and starts growth early in the spring. It closely resembles Italian rye-grass and meadow fescue when young, from which it is readily distinguished by its folded leaf bud.

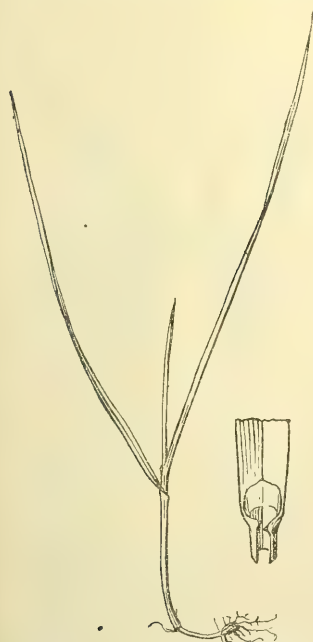


FIG. 5.—Perennial rye-grass (*Lolium perenne*).¹



FIG. 6.—St. Augustine grass (*Stenotaphrum americanum*).

2. Carpet grass (*Axonopus compressus*).

A perennial grass with creeping stolons, forming a dense turf; leaves folded in the bud; collar narrow, indistinct, with a few hairs at margins; auricles none; ligule a fringe of short hairs; sheaths glabrous, diverging from stems; blades flat, usually short, linear, about one-eighth to one-

¹ Each figure shows a young plant and a detailed drawing of the leaf at the collar illustrating the ligule and other appendages.

fourth inch wide, round pointed; stolons compressed, about one-eighth inch in diameter.¹

This grass is seldom found north of Tennessee or North Carolina, but it is common on the sandy soils of the Gulf States.

3. Poverty grass (*Danthonia spicata*; fig. 7).

A tufted perennial; leaves folded in the bud; collar narrow, continuous, hairy; auricles none; ligule a fringe of short hairs; blades often curled, glabrous, rough on the under surface and margins, about one-eighth inch wide, sharp pointed.

This grass is often found on poor sandy soils. The leaves, frequently curled, form a small rounded tuft.

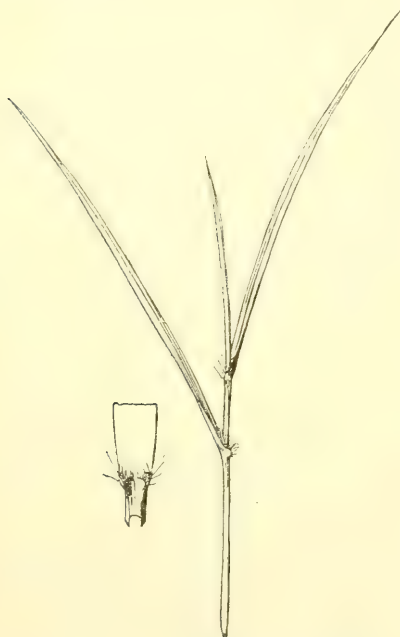


FIG. 7.—Poverty grass (*Danthonia spicata*).

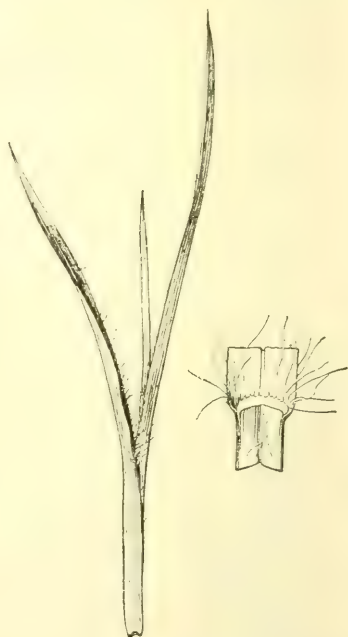


FIG. 8.—Broom sedge (*Andropogon virginicus*).

4. Broom sedge (*Andropogon virginicus*; fig. 8).

A coarse, tufted perennial; leaves folded in the bud; collar small, hairy, in two parts, separated in the middle by a broad gap; auricles none; ligule membranous, hairy on the back and fringed with long hairs; sheaths much compressed, hairy along the margins, merging indistinctly into the blade; blades compressed near base, hairy along margins, about one-fourth inch wide, sharp pointed.

The remains of the previous year's growth persist as tough, woody, buff-colored tufts. This grass is readily recognized by its peculiar collar, folded leaf bud, and strongly compressed sheaths and blades.

¹ St. Augustine grass (*Stenotaphrum americanum*) would also trace to this place. It very closely resembles carpet grass when young, but differs from it in the fact that the collar is very much constricted (fig. 6).

5. **Yard-grass** (*Eleusine indica*; fig. 9).

A tufted annual, decumbent at base; leaves folded in the bud; collar broad, continuous, hairy; auricles none; ligule membranous, medium long, coarsely toothed; sheaths white near the ground, green above, strongly compressed, sparsely hairy along the margins; blades V-shaped in cross section, about one-fourth inch wide, sparsely hairy above, tough in texture, linear, obtuse pointed.

This is a common summer grass, making conspicuous tufts in lawns.

6. **Crested dog's-tail grass** (*Cynosurus cristatus*; fig. 10).

A slender, erect, tufted perennial; leaves folded in the bud; collar broad, continuous, glabrous; auricles none; ligule membranous, medium long, truncate, toothed, continuous with the margins of the sheath; sheaths not compressed, glabrous, bright yellow below ground; blades glossy below, prominently nerved above, flat one-fourth inch wide, sharp pointed.

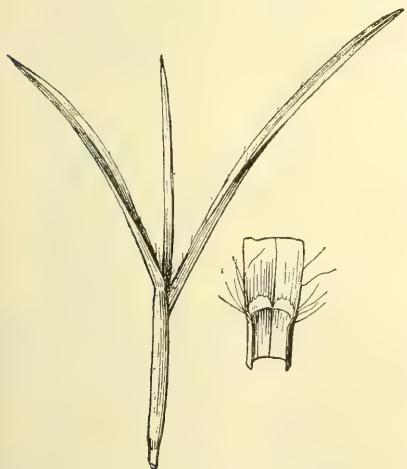


FIG. 9.—Yard-grass (*Eleusine indica*).

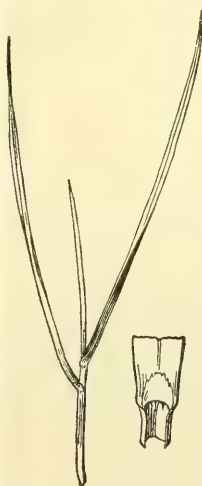


FIG. 10.—Crested dog's-tail (*Cynosurus cristatus*).



FIG. 11.—Sheep's fescue (*Festuca ovina*).

7. **Sheep's fescue** (*Festuca ovina*; fig. 11).

A densely tufted perennial; leaves folded in the bud; collar narrow, indistinct, glabrous; auricles short, obtuse; ligule membranous, very short; sheaths finely pubescent when viewed under a lens, not compressed, the old ones remaining as dark-brown fibers; blades long, linear, thick, bristle-like, about one-sixteenth inch wide, pale bluish green.

8. **Red fescue** (*Festuca rubra*; fig. 12).

A fine glabrous perennial grass with creeping rootstocks; leaves folded in the bud; collar narrow, indistinct, glabrous; auricles none; ligule membranous, short, entire, acute; sheaths minutely roughened, wider than blades, not compressed, the old ones remaining as brownish red fibers; blades long, linear, thick, bristlelike, one-sixteenth inch or less wide, dark green; rootstocks fine, branching, producing tufts of shoots.¹

¹ In some forms of velvet bent (*Agrostis canina*) it is difficult to determine whether the leaf is folded or rolled in the bud. It may be distinguished from red fescue by its soft, flat blades, which are prominently nerved. The old leaf sheaths of velvet bent are grayish white in color instead of brown, as in red fescue.

This grass is distinguished from sheep's fescue by its finer leaves, more acute ligule, and habit of growth. Red fescue produces a fine even turf.



FIG. 12.—Red fescue (*Festuca rubra*).

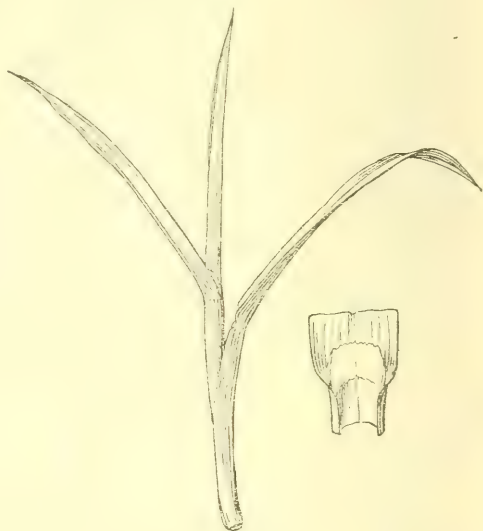


FIG. 13.—Orchard grass (*Dactylis glomerata*).

9. Orchard grass (*Dactylis glomerata*; fig. 13).

A tufted, glabrous perennial; leaves folded in the bud; collar broad, prominent, yellow; auricles wanting; ligule thin, membranous, very long, often lacerate; sheaths white below, green above, strongly compressed, the

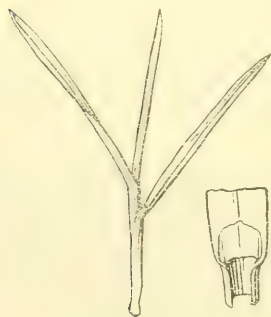


FIG. 14.—Annual bluegrass (*Poa annua*).

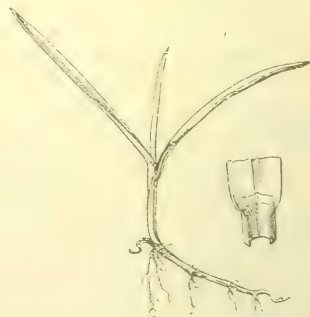


FIG. 15.—Canada bluegrass (*Poa compressa*).

edges united below into a closed tube; blades long, soft, V-shaped in cross section, usually one-fourth inch or more wide, sharp pointed, pale green in color.

This is a common meadow grass and is often found in pastures. It starts growth early in the spring.

10. Annual bluegrass (*Poa annua*; fig. 14).

A low-growing, glabrous, tufted annual; leaves folded in the bud; collar glabrous; auricles none; ligule medium long, acute, entire; sheaths compressed, glabrous; blades flat, short, linear, pale yellowish green, one-eighth inch wide.

This grass often heads out when but 1 inch high. Rootstocks are rare; when present, very short. In the South it makes considerable winter growth. Two white lines along the midnerve may be noticed by holding a blade up to the light and examining with a lens.

11. Canada bluegrass (*Poa compressa*; fig. 15).

A glabrous, bluish green perennial with creeping rootstocks forming a loose turf; leaves folded in the bud; collar light green; auricles none; ligule membranous, entire, acute, medium long; sheaths strongly compressed, often tinged with red; blades flat, long, linear, the apex like the bow of a boat, bluish green but with double light lines along the midnerve when viewed by transmitted light; rootstocks about one-sixteenth inch in diameter, each branch usually terminating in a single shoot.

This grass has more of a bluish color and grows in looser turf than Kentucky bluegrass, with which it is most likely to be confused.

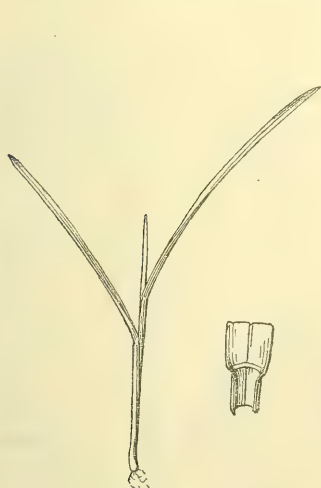


FIG. 16.—Kentucky bluegrass (*Poa pratensis*).

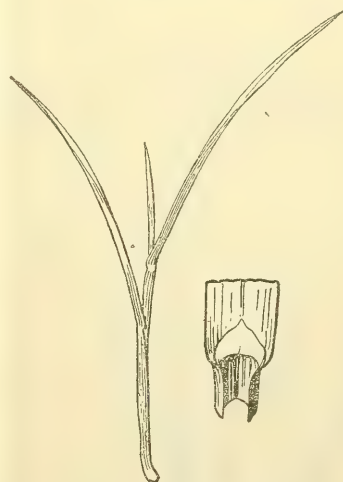


FIG. 17.—Rough-stalked meadow grass (*Poa trivialis*).

12. Kentucky bluegrass (*Poa pratensis*; fig. 16).

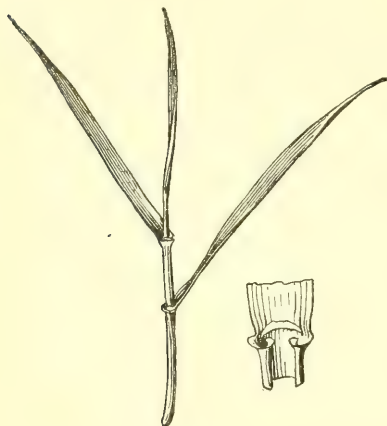
A dark-green perennial, creeping by rootstocks and forming a dense turf; leaves folded in the bud; collar narrow, glabrous; auricles none, ligule membranous, very short, truncate, entire; sheaths green, smooth, compressed; blade long, linear, less than one-eighth inch wide, the tip abrupt pointed like the bow of a boat, dark green, but with two light lines along the midnerve when viewed by transmitted light; rootstocks slender, branching, producing tufts with several shoots.

13. Rough-stalked meadow grass (*Poa trivialis*; fig. 17).

A dark-green, glabrous perennial, creeping by stolons; leaves folded in the bud; collar wide, glabrous; auricles none; ligule long, membranous, toothed at apex; sheaths compressed, closed, rough to the touch; blades

one-eighth inch wide, tapering to the tip; creeping stems always above ground, giving off clusters of shoots.

This grass is distinguished from Kentucky bluegrass by being coarser and rough, by the ligule, and by the above-ground stolons, the creeping stems of Kentucky bluegrass being always below ground.



14. Italian rye-grass (*Lolium multiflorum*; fig. 18).

A tufted, glabrous annual, or sometimes perennial; leaves rolled in the bud; collar prominent; auricles narrow and clawlike; ligule membranous, short, thin, obtuse; sheaths not compressed, strongly nerved, violet pink below ground; blades three-sixteenths inch wide, taper pointed, smooth on the margins, prominently nerved on the upper surface, glossy beneath; nerves small, separated by light-green lines when viewed by transmitted light.

FIG. 18.—Italian rye-grass (*Lolium multiflorum*).

This grass is very similar to perennial rye-grass and meadow fescue. It is distinguished from meadow fescue by the smooth leaf margins and the nervation of the blades when held up to the light and viewed with a lens. It is distinguished from perennial rye-grass by its leaf bud, Italian rye-grass being convolute and perennial rye-grass folded.

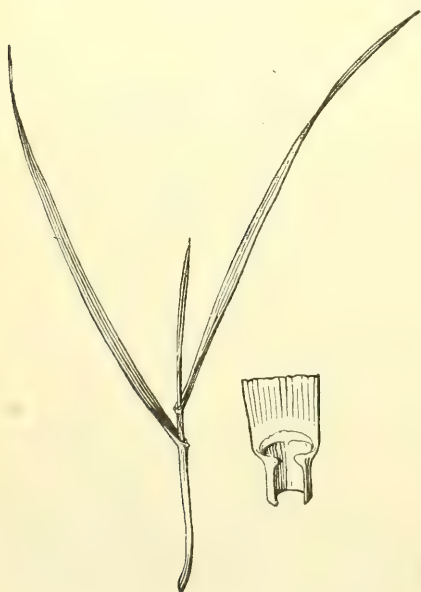


FIG. 19.—Meadow fescue (*Festuca elatior*).



FIG. 20.—Quack-grass (*Agropyron repens*).

15. Meadow fescue (*Festuca elatior*; fig. 19).

A tufted, glabrous, dark-green perennial; leaves rolled in the bud; collar broad, continuous; auricles none; ligule membranous, short, truncate;

sheaths not compressed, reddish pink below ground; blades flat, sharp pointed, rough on the margins, glossy beneath, nerved above, three-sixteenths inch wide; nerves separated into pairs by white lines when viewed by transmitted light.

This grass closely resembles both Italian rye-grass and perennial rye-grass. It may be distinguished from Italian rye-grass by its rough-margined blades (test with the tongue) and also by the nerves in the blades. Perennial rye-grass is distinguished by having its leaves folded in the bud.

16. **Quack-grass** (*Agropyron repens*; fig. 20).

A pale-green perennial, creeping by its long rootstocks; leaves rolled in the bud; collar broad, continuous, hairy; auricles slender, clawlike; ligule membranous, short, entire; sheaths hairy, not compressed; blades flat, finely hairy at the base, sharp pointed, one-fourth inch wide; nerves broad, not prominent; rootstocks strong, elongate, one-eighth inch or more in diameter.

This is a common, very aggressive grass. The hairs, while quite noticeable in the spring, are often invisible in the fall unless a lens is used.

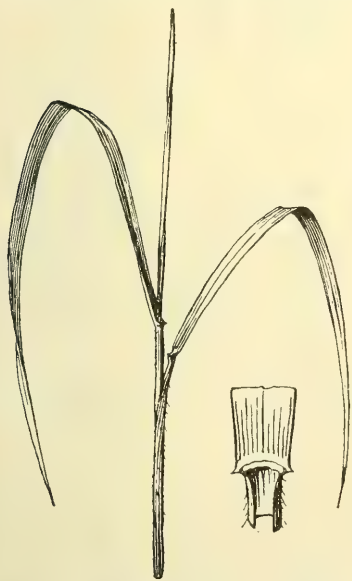


FIG. 21.—Virginia wild rye (*Elymus virginicus*).

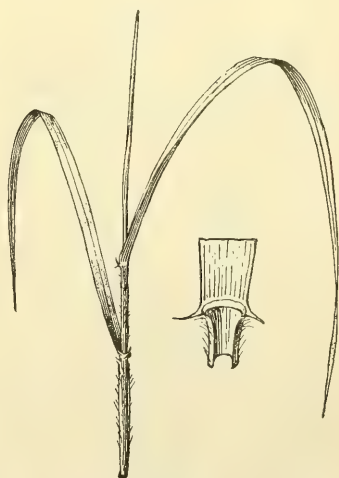


FIG. 22.—Slender wild rye (*Elymus striatus*).

17. **Virginia wild rye** (*Elymus virginicus*; fig. 21).

A loosely tufted perennial; leaves rolled in the bud; collar broad, glabrous, continuous; auricles short, clawlike; ligule membranous, very short, entire; sheaths not compressed, glabrous, fine veined, retrorsely hairy; blades flat, glabrous, dull above, glossy beneath, rough on the margins, one-fourth to one-half inch broad, sharp pointed; nerves small, indistinct.

This grass resembles the small grains in habit of growth.

18. **Slender wild rye** (*Elymus striatus*; fig. 22).

A loosely tufted perennial; leaves rolled in the bud; collar narrow, glabrous, continuous; auricles long, slender, clawlike, overlapping; ligule short, membranous, entire; sheaths not compressed, hairy, the hairs point-

ing upwards; blades flat, glossy beneath, dull and densely pubescent above and velvety to the touch, rough on the margins, one-fourth inch wide, sharp pointed.

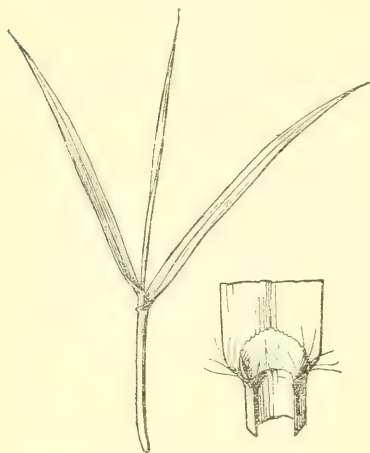


FIG. 23.—Sweet vernal grass (*Anthoxanthum odoratum*).

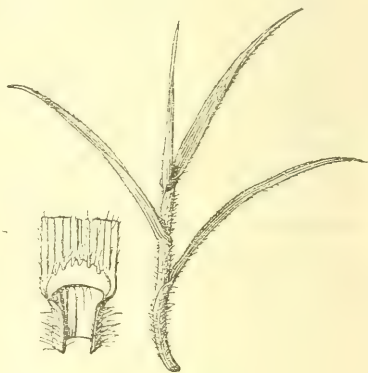


FIG. 24.—Soft chess (*Bromus hordeaceus*).

19. Sweet vernal grass (*Anthoxanthum odoratum*; fig. 23).

A low-growing tufted perennial; leaves rolled in the bud; collar broad, hairy; auricles none; ligule long, obtuse, membranous; sheaths glabrous, not compressed; blades flat, the margins rough and sometimes sparsely hairy near the base, one-fourth inch wide, sharp pointed.

This grass is easily recognized by its sweet odor, which becomes more pronounced in drying.



FIG. 25.—Switch-grass (*Panicum virgatum*).

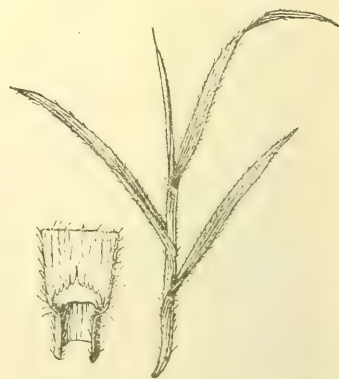


FIG. 26.—Downy brome-grass (*Bromus tectorum*).

20. Soft chess (*Bromus hordeaceus*; fig. 24).

A slender, tufted annual; leaves rolled in the bud; collar broad, with wavy margins, glabrous; auricles none; ligule membranous, medium long,

truncate, toothed, hairy on the back; sheaths with reddish pink veins, not compressed, densely hairy; blades flat, hairy, one-fourth inch wide, sharp pointed; nerves distinct, separated by dark-brown lines.

21. Switch-grass (*Panicum virgatum*; fig. 25).

A coarse perennial, creeping by rootstocks; leaves rolled in the bud; collar broad, continuous, hairy; auricles none; ligule a fringe of short hairs, in front of a tuft of fine, soft hairs at the base of the blade; sheaths not compressed, hairy along the margins near the top; blades flat, narrowed at base, one-fourth to one-half inch wide, taper pointed; rootstocks strong, one-eighth inch or more in diameter.

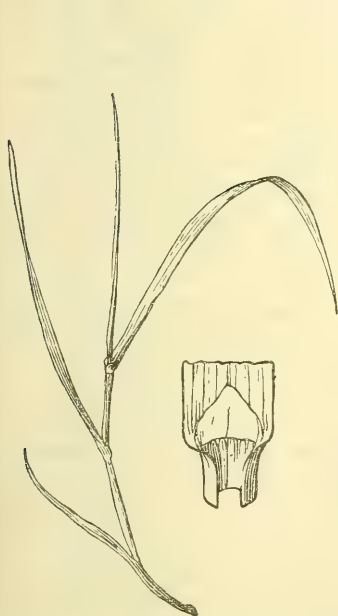


FIG. 27.—Meadow foxtail (*Alopecurus pratensis*).



FIG. 28.—Reed canary grass (*Phalaris arundinacea*).

22. Downy brome-grass (*Bromus tectorum*; fig. 26).

A slender, tufted annual; leaves rolled in the bud; collar narrow, continuous, hairy; auricles none; ligule medium long, acute, hairy on the margin near the apex; sheaths not compressed, hairy, veiny, the veins pinkish below ground; blades flat, weak, hairy, one-fourth inch wide, sharp pointed.

23. Meadow foxtail (*Alopecurus pratensis*; fig. 27).

A glabrous perennial with short rootstocks; leaves rolled in the bud; collar broad, glabrous; auricles none; ligule membranous, long, obtuse; sheaths smooth, not compressed, dark violet to maroon below ground; blades flat, one-fourth inch wide, rough on the upper surface and along the margins; rootstocks strong, branched, short, partly above ground, each terminating in a single shoot.

24. Reed canary grass (*Phalaris arundinacea*; fig. 28).

A coarse, glabrous perennial with stout rootstocks; leaves rolled in the bud; collar broad, spiral, with wavy margins; auricles none; ligule very long, obtuse, membranous, often torn, hairy on the back, wider than the sheaths; sheaths not compressed, hyaline on the margins; blades flat, rough on the margins, one-half inch or more wide, sharp pointed; rootstocks more than one-eighth inch in diameter.¹

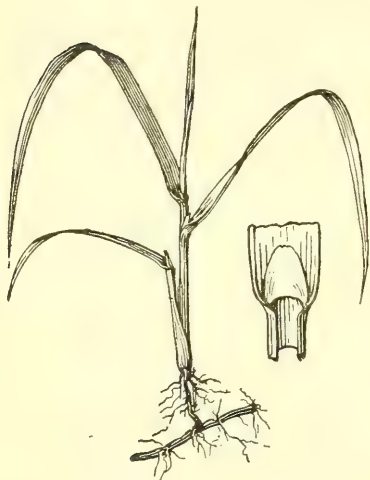


FIG. 29.—Redtop (*Agrostis alba*).

25. Redtop (*Agrostis alba*; fig. 29).

A dark-green, glabrous perennial, creeping by rootstocks; leaves rolled in the bud; collar narrow, divided into two parts by a space, glabrous; auricles none; ligule membranous, thin, very long, acute, finely toothed; sheaths smooth, not compressed; blades flat, distinctly nerved above, rough margined, one-fourth inch or more wide, sharp pointed; rootstocks about one-sixteenth inch in diameter.

Redtop, when young, resembles timothy, from which it is distinguished by its ligule, rootstocks, and coarsely nerved leaves.

26. Creeping bent (*Agrostis stolonifera*; fig. 30, A).

A fine-leaved glabrous perennial, creeping by rootstocks; leaves rolled in the bud; collar narrow; auricles none; ligule short, rather obtuse; sheaths

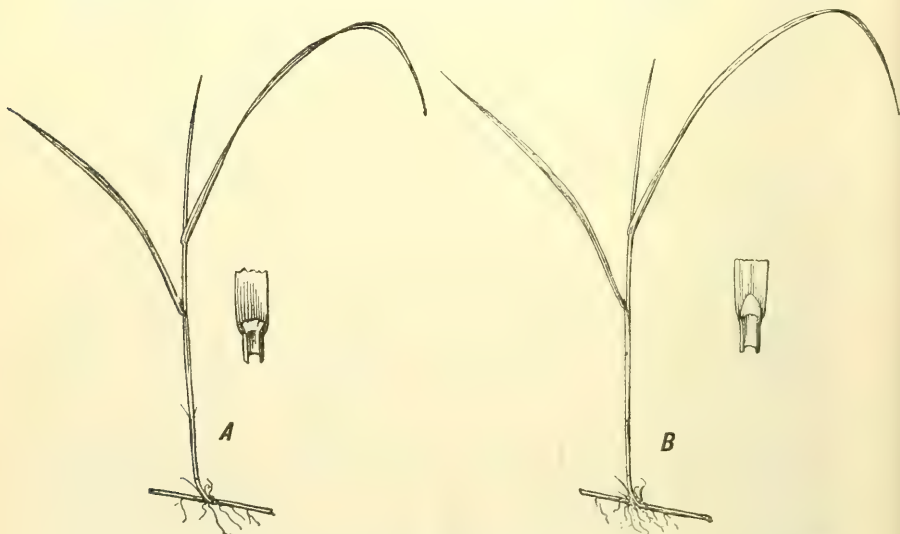


FIG. 30.—A, Creeping bent (*Agrostis stolonifera*); B, velvet bent (*Agrostis canina*).

smooth, not compressed; blades flat, distinctly nerved above, one-eighth inch or less wide, taper pointed; rootstocks very fine, branching, producing numerous tufts.

¹ A variety of this grass called ribbon grass and grown for ornamental purposes is readily recognized by its green leaves striped with white.

This grass produces a fine, dense turf. Velvet bent (*Agrostis canina*; fig. 30, *B*) is similar to creeping bent, but grows in a still finer turf and is distinguished by a long acute ligule and by scabrous blades when viewed with a lens.

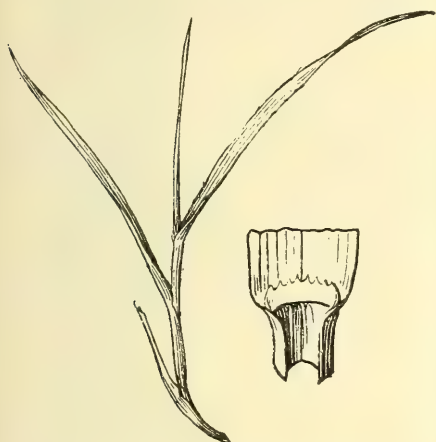


FIG. 31.—Chess (*Bromus secalinus*).

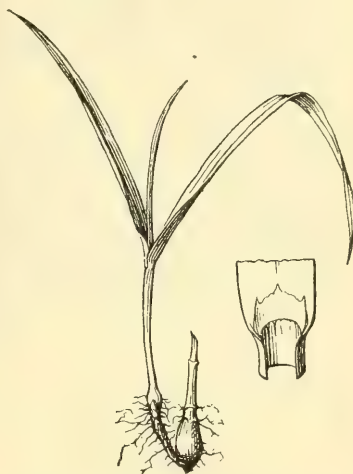


FIG. 32.—Timothy (*Phleum pratense*).

27. Chess (*Bromus secalinus*; fig. 31).

A tufted, pale-green annual; leaves rolled in the bud; collar broad, glabrous; auricles none; ligule short, membranous, toothed near the tip;

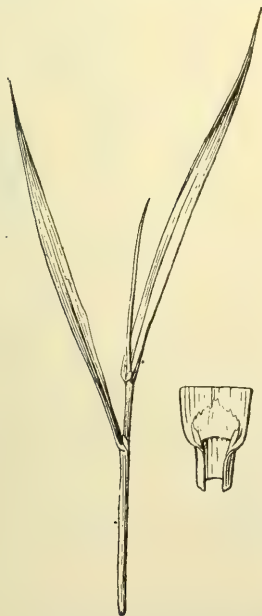


FIG. 33.—Tall oat-grass
(*Arrhenatherum elatius*).

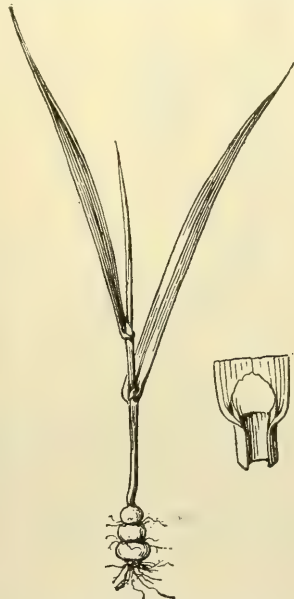


FIG. 34.—Bulbous oat-grass
(*Arrhenatherum elatius*
bulbosum).

sheaths not compressed, glabrous, rarely hairy, pink veined; blades flat, glabrous, or sometimes sparsely hairy above, one-fourth inch wide.

This grass is often found in fields of winter grain.

28. Timothy (*Phleum pratense*; fig. 32).

A stout, glabrous, tufted perennial; leaves rolled in the bud; collar broad, continuous; auricles none; ligule membranous, short, obtuse, the apex usually with several large teeth; sheaths not compressed; blades flat, indistinctly nerved, rough on the margins, one-fourth inch wide, sharp pointed.

The thickened base, or "corm," of the old stem usually may be found attached above the young plant below ground.

29. Tall oat-grass (*Arrhenatherum elatius*; fig. 33).

A loosely tufted perennial; leaves rolled in the bud; collar broad, divided into two parts by a space, glabrous; auricles none; ligule membranous, medium long, obtuse, finely toothed at apex, hairy on the back, sheaths not compressed, usually glabrous, sometimes sparsely hairy, prominently nerved; blades flat, linear, one-half inch or more wide, sharp pointed; nerves in pairs, not prominent, separated by white lines as seen by transmitted light.

30. Bulbous oat-grass (*Arrhenatherum elatius bulbosum*; fig. 34).

A loosely tufted perennial; leaves rolled in the bud; collar broad, glabrous, divided into two parts by a gap; auricles none; ligule membranous, medium long, obtuse, finely toothed at apex, hairy on the back; sheaths not compressed, usually

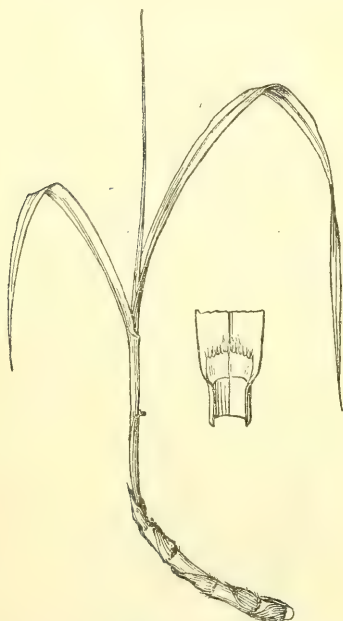


FIG. 35.—Johnson grass (*Andropogon halepensis*).

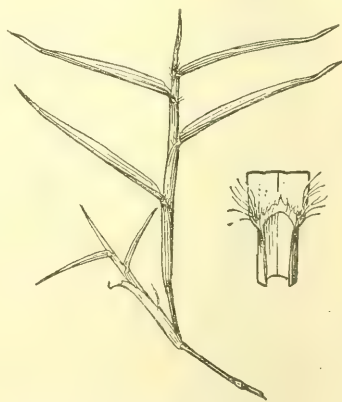


FIG. 36.—Nimble Will (*Muhlenbergia schreberi*).

glabrous, sometimes sparsely hairy, prominently nerved; blades flat, linear, one-fourth inch or more wide, sharp pointed; nerves in pairs, separated by white lines when viewed by transmitted light.

There is a chain of from two to five bulbous growths at the base of the stems below ground which distinguishes this grass from tall oat-grass. Bulbous oat-grass has been recently introduced into this country and is occasionally found in eastern Virginia and North Carolina.

31. Johnson grass (*Andropogon halepensis*; fig. 35).

A nearly glabrous perennial, creeping by rootstocks; leaves rolled in the bud; collar broad; auricles none; ligule membranous, long, obtuse, lacerate ciliate at top; sheaths compressed, glabrous, usually pale, the outer ones sometimes reddish brown; blades flat, narrowed at base, and hairy at the very base, one-half inch or more wide, sharp pointed; midnerve white, very thick; rootstocks one-fourth inch or more in diameter.

32. Nimble Will (*Muhlenbergia schreberi*; fig. 36).

A pale-green, glabrous perennial, creeping by stolons; leaves rolled in the bud; collar narrow, glabrous; auricles none; ligule membranous, short, lacerate; sheaths compressed, loose; blades short when young, soft and flat; stolons very slender, hard, wiry, much branched, the joints one-half to 1 inch long.

Often the fine, very much branched stolons of this grass lie off the ground and take root only when the joints come in contact with the soil.

33. Barnyard grass (*Echinochloa crus-galli*; fig. 37).

A coarse, nearly glabrous, tufted annual; leaves rolled in the bud; collar broad, continuous, glabrous; auricles none; ligule wanting; sheaths compressed, the outer ones with pink nerves, the inner ones pale; blades flat, narrowed at base, the midnerve thick, sometimes sparsely hairy along the margins near the base, one-half inch or more wide, sharp pointed.



FIG. 37.—Barnyard grass (*Echinochloa crus-galli*).

FIG. 38.—Sudan grass (*Andropogon sorghum sudanensis*).

34. Sudan grass (*Andropogon sorghum sudanensis*; fig. 38).

A coarse, nearly glabrous annual; leaves rolled in the bud; collar broad, continuous, glabrous; auricles none; ligule membranous, long, lacerate, wider than the sheaths; sheaths slightly compressed, hyaline margined; blades flat, narrowed at base, pale green above, one-half inch or more wide, sharp pointed; midnerve thick, pale green.

This grass is similar to Johnson grass, but it does not have rootstocks. The midnerve is also distinctive.

35. Yellow foxtail (*Chaetochloa lutescens*; fig. 39).

A coarse, tufted annual; leaves rolled in the bud; collar narrow, yellow, continuous, glabrous; auricles none; ligule a fringe of short hairs; sheaths compressed, glabrous; blades flat near the base, hairy on the upper surface, one-fourth inch or more wide, sharp pointed.

36. **Spreading witch-grass** (*Panicum dichotomiflorum*; fig. 40).

A coarse, tufted, glabrous annual; leaves rolled in the bud; collar broad, continuous, glabrous; auricles none; ligule a fringe of hairs; sheaths slightly compressed, glabrous; blades flat, glossy beneath, dull above, one-half inch wide, sharp pointed; midnerve light green, slightly rough.

37. **Rescue grass** (*Bromus unioloides*; fig. 41).

A coarse, tufted grass, annual or sometimes perennial; leaves rolled in the bud; collar broad, continuous, hairy; auricles none; ligule long, membranous, entire, hairy on the back; sheaths strongly compressed, hairy, the older ones with pink nerves; blades flat, sparsely hairy, one-half inch wide.

This grass makes considerable winter growth in the Southern States.

38. **Velvet grass** (*Holcus lanatus*; fig. 42).

A pale, tufted, hairy perennial; leaves rolled in the bud; collar continuous, hairy; auricles none; ligule short, membranous, coarsely toothed at apex, hairy on the back; sheaths compressed, pink nerved, densely hairy; blades flat, soft, hairy, one-half inch wide, sharp pointed.

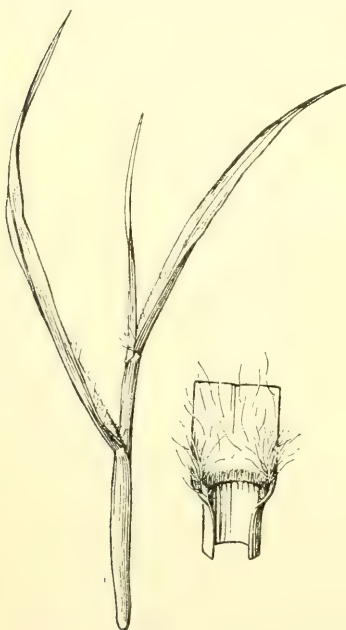


FIG. 39.—Yellow foxtail (*Chaetochloa lutescens*).

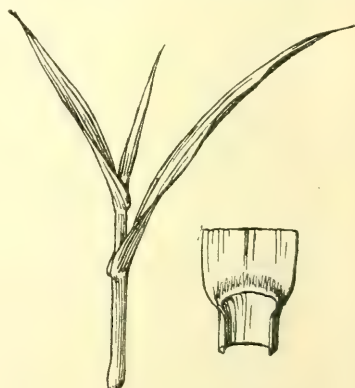


FIG. 40.—Spreading witch-grass (*Panicum dichotomiflorum*.)

39. **Crab-grass** (*Syntherisma sanguinalis*; fig. 43).

A pale-green annual, creeping by stolons; leaves rolled in the bud; collar broad, prominent, sparsely hairy; auricles none; ligule membranous, long, acute, toothed; sheaths compressed, hairy; blades flat, sparsely hairy, wavy margined, one-fourth inch wide, sharp pointed; stolons about one-sixteenth inch in diameter, much branched.

40. **Small crab-grass** (*Syntherisma ischaemum*; fig. 44).

A low-growing annual, creeping by stolons; leaves rolled in the bud; collar broad, sparsely hairy; auricles none; ligule membranous, long, entire; sheaths compressed, glabrous; blades flat, sparsely hairy at base, otherwise glabrous, one-fourth inch wide, sharp pointed; stolons about one-sixteenth inch in diameter, branched.

41. Field paspalum (*Paspalum laeve*; fig. 45).

A coarse, tufted perennial; leaves rolled in the bud (fig. 4, C); collar hairy, broad, continuous; auricles none; ligule membranous, thin, acute,

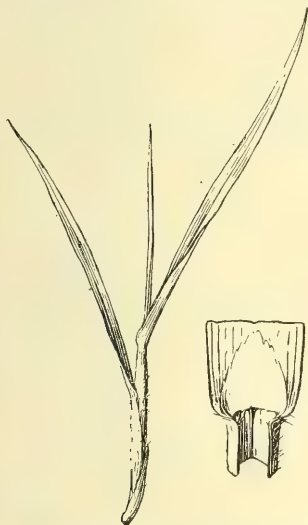


FIG. 41.—Rescue grass (*Bromus unioloides*).

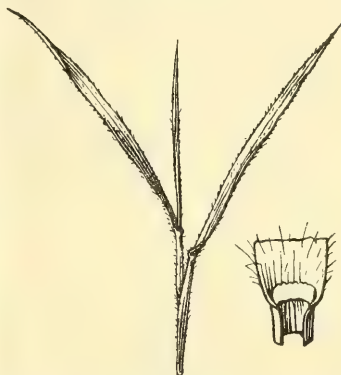


FIG. 42.—Velvet grass (*Holcus lanatus*).

long; sheaths strongly compressed, sparsely hairy on the margins and mid-nerve; blades flat, hairy above, near the base, and along the margins, one-fourth inch wide, sharp pointed, tinged with reddish brown near tips.

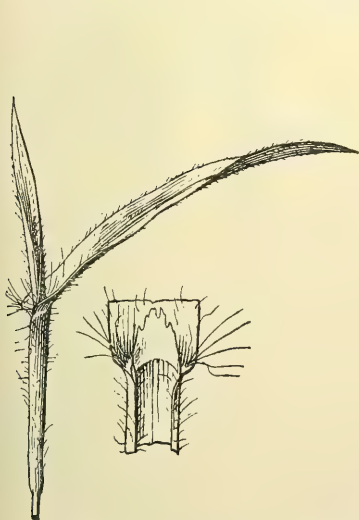


FIG. 43.—Crab-grass (*Syntherisma sanguinalis*).

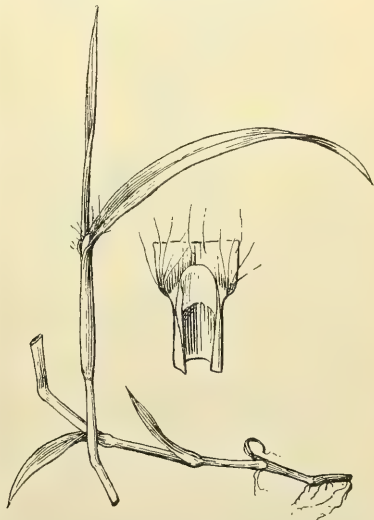


FIG. 44.—Small crab-grass (*Syntherisma ischaemum*).

This grass very closely resembles smooth paspalum, false redtop, and flat-stemmed panic when young. The blades are usually creased lengthwise from the manner in which they are rolled in the bud. It starts growth in late spring.

42. Smooth paspalum (*Paspalum dilatatum*; fig. 46).

A coarse, tufted perennial; leaves rolled in the bud; collar medium broad, continuous, hairy; auricles none; ligule membranous, thin, acute, long; sheaths strongly compressed, densely hairy below, sparsely so above; blades sparsely hairy at base, one-fourth inch wide, sharp pointed, thin, narrowed at base.

Smooth paspalum is a taller growing grass than field paspalum, which it closely resembles. The densely hairy sheaths and usually darker green color are characteristic. It is often grown in the Southern States for hay. The membranous ligule distinguishes this grass from false redtop and flat-stemmed panic.

43. Bermuda grass (*Capriola dactylon*; fig. 47).

A low-growing perennial, creeping by rootstocks or stolons, or both; leaves rolled in the bud; collar narrow, with a ring of stiff hairs; auricles none; ligule a fringe of short hairs; sheaths strongly compressed, sparsely hairy; blades soft, rough margined, one-eighth inch wide, sharp pointed; rootstocks one-eighth inch in diameter, mostly below ground, but becoming stolons on hard soil.

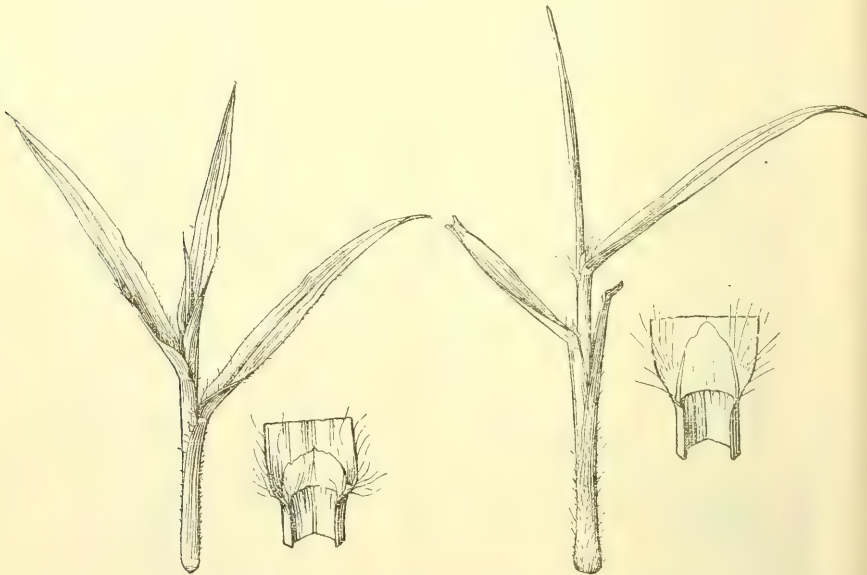


FIG. 45.—Field paspalum (*Paspalum laeve*).

FIG. 46.—Smooth paspalum (*Paspalum dilatatum*).

44. False redtop (*Tridens flavus*; fig. 48).

A coarse, tufted perennial; leaves rolled in the bud (fig. 4, C); collar hairy on the back; auricles none; ligule a fringe of short hairs; sheaths strongly compressed, tough, firm, smooth, glossy, slightly hairy on the upper margins; blades narrowed at base, taper pointed, minutely hairy above, smooth and glossy beneath, one-half inch wide, sharp pointed.

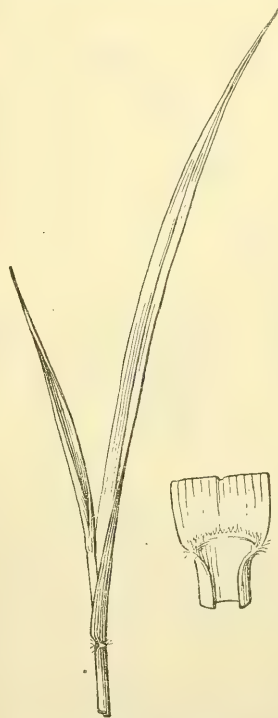
This grass closely resembles the field and the smooth paspalums, from which it is distinguished by its ligule, and flat-stemmed panic, from which it differs in not having rootstocks. The leaves are creased lengthwise from the manner in which they are rolled in the bud.

45. Green foxtail (*Chaetochloa viridis*; fig. 49).

A coarse, tufted annual; leaves rolled in the bud; collar narrow, hairy; auricles none; ligule a fringe of hairs, longest near the margins; sheaths slightly compressed above, hairy along the margins; blades soft, flat, narrowed at base, one-fourth to one-half inch wide, sharp pointed.

46. Flat-stemmed panic (*Panicum anceps*; fig. 50).

A coarse perennial with short rootstocks; leaves rolled in the bud (fig. 4, C); collar hairy on back and margins; auricles none; ligule a fringe

FIG. 47.—Bermuda grass (*Capriola dactylon*).FIG. 48.—False redtop (*Tridens flavus*).

of short hairs; sheaths strongly compressed, glossy, usually glabrous; blades sparsely hairy on upper surface near base, three-eighths to one-half inch wide, sharp pointed.

This grass closely resembles the field and smooth paspalums, from which it is distinguished by its hairy ligule and rootstocks, and also false redtop, from which it differs in the presence of rootstocks.

47. Slender meadow grass (*Eragrostis pilosa*; fig. 51).

A slender, tufted annual; leaves rolled in the bud; collar narrow, hairy; auricles none; ligule a fringe of hairs; sheaths slightly compressed, glabrous; blades dull and sparsely hairy above, glossy below, less than one-eighth inch wide, sharp pointed.

It closely resembles stink-grass, but it is not so large.

48. Stink-grass (*Eragrostis cilianensis*; fig. 52).

A slender, tufted, often decumbent annual; leaves rolled in the bud; collar narrow, hairy; auricles none; ligule a fringe of hairs; sheaths glabrous,

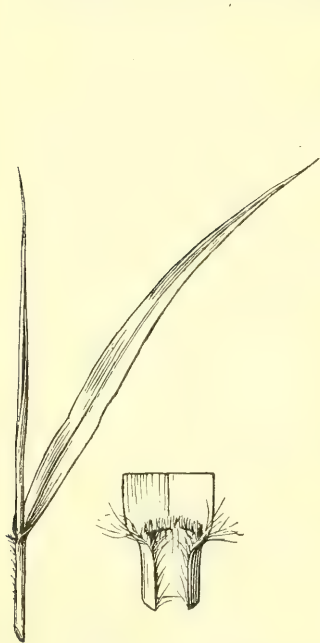


FIG. 49.—Green foxtail (*Chachyloa viridis*).

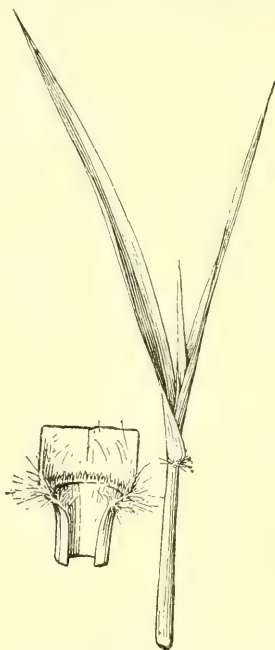


FIG. 50.—Flat-stemmed panic (*Panicum anceps*).

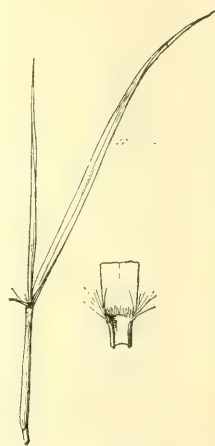


FIG. 51.—Slender meadow grass (*Eragrostis pilosa*).

slightly compressed; blades flat, dull, and sparsely hairy above, glossy beneath, one-eighth inch wide.

Stink-grass is very similar to slender meadow grass except that the plants of stink-grass are about twice as large as those of slender meadow grass. In most botanical works this grass is called *Eragrostis major*.

IDENTIFICATION OF SMALL-GRAIN SEEDLINGS.

The seedlings of small grains are, under all conditions, very difficult to identify. Men who are constantly growing these grains usually learn to distinguish the different species. Even certain varieties in a species are sometimes recognizable. But there is great variation even in the different varieties, and the varietal differences in each species make it difficult to find a combination of characters that will always hold true for the species.

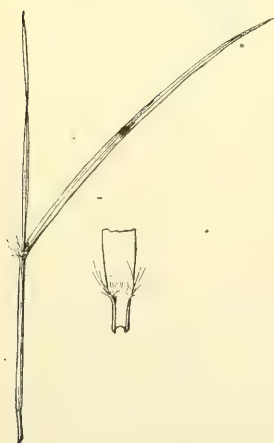


FIG. 52.—Stink-grass (*Eragrostis cilianensis*).

All of the small grains so far as studied have their leaves rolled in the bud. The most dependable characters are found in the collar,

the presence or absence of claws, the pubescence and the general shape of the blades, especially at the tips. The ligules of all are very similar, the principal differences being in shape and length.

ANALYTICAL KEY TO SMALL-GRAIN SEEDLINGS.

A. Collar without clawlike appendages.

49. Oats (*Avena sativa*).

AA. Collar with clawlike appendages which clasp the stem more or less.

B. Claws hairy.

C. Sheaths and blades finely pubescent, soft, and velvety.

50. Emmer (*Triticum dicoccum*).

CC. Sheaths and blades not pubescent.

D. Collar and claws large.

51. Spelt (*Triticum spelta*).

DD. Collar and claws slender.

52. Wheat (*Triticum aestivum*).

BB. Claws not hairy.

C. Collar and claws large and prominent.

D. Nerves of blades not prominent, upper surface rough.

53. Barley (*Hordeum sativum*).

DD. Nerves of blades broad and prominent, smooth on upper surface.

54. Polish wheat (*Triticum polonicum*).

CC. Collar and claws slender.

D. Blades and sheaths sparsely hairy.

55. Rye (*Secale cereale*).

DD. Blades and sheaths free from hairs.

56. Durum wheat (*Triticum durum*).

DETAILED DESCRIPTIONS OF EIGHT SMALL-GRAIN SEEDLINGS.

49. Oats (*Avena sativa*; fig. 53).

Collar broad, separated into two parts by midnerve, free from claws, finely hairy; ligule membranous, long, acute, toothed; sheaths sparsely hairy; blades hairy along margins, flat, rough, one-half inch wide.

The blades are longer and more tapering pointed than those of wheat. Some varieties of spring oats are free from hairs on sheaths and blades. Spring oats have a more upright habit of growth than the winter varieties.

50. Emmer (*Triticum dicoccum*; fig. 54).

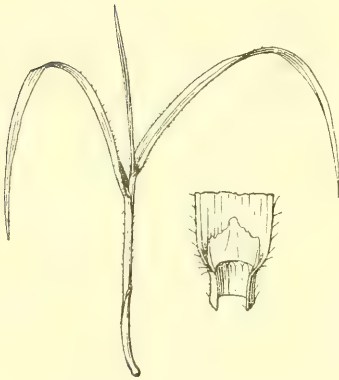
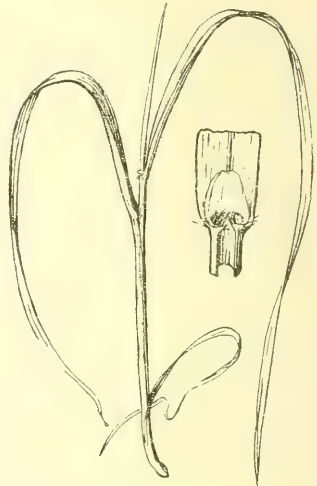
Collar medium broad, with claws; collar and claws sparsely hairy; ligule thin, membranous, acute, toothed; sheaths finely pubescent, soft and velvety, the hairs seen only with a lens, one-fourth inch wide, sharp pointed; blades prominently nerved.

51. Spelt (*Triticum spelta*; fig. 55).

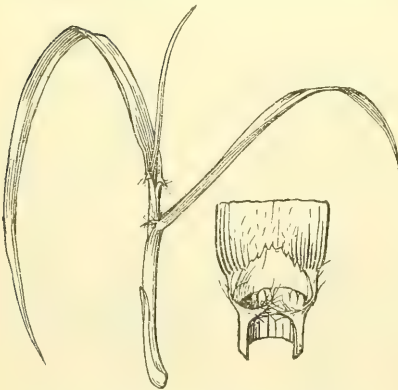
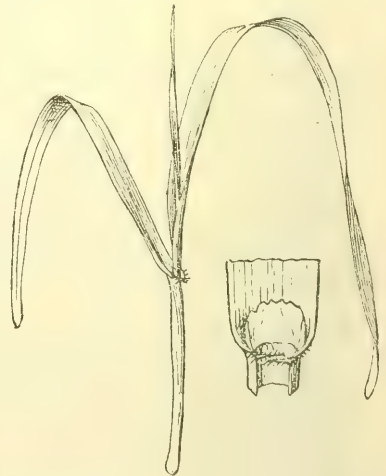
Collar broad, similar to that of barley, with large, hairy claws; ligule membranous, medium long, toothed, acute; sheaths free from hairs; blades free from hairs near base except a few at margins, one-fourth inch or more wide, sharp pointed on older, abrupt on younger plants; nerves small.

52. Wheat (*Triticum aestivum*; fig. 56).

Collar broad, not spiral, continuous, with small, slender claws, hairy along margins and claws; ligule long, truncate, toothed; sheaths not keeled, free from hairs; blades long, free from hairs, smooth, flat, the older ones abrupt pointed, one-half inch wide.

FIG. 53.—Oats (*Avena sativa*).FIG. 54.—Emmer (*Triticum dicoccum*).53. Barley (*Hordeum sativum*; fig. 57).

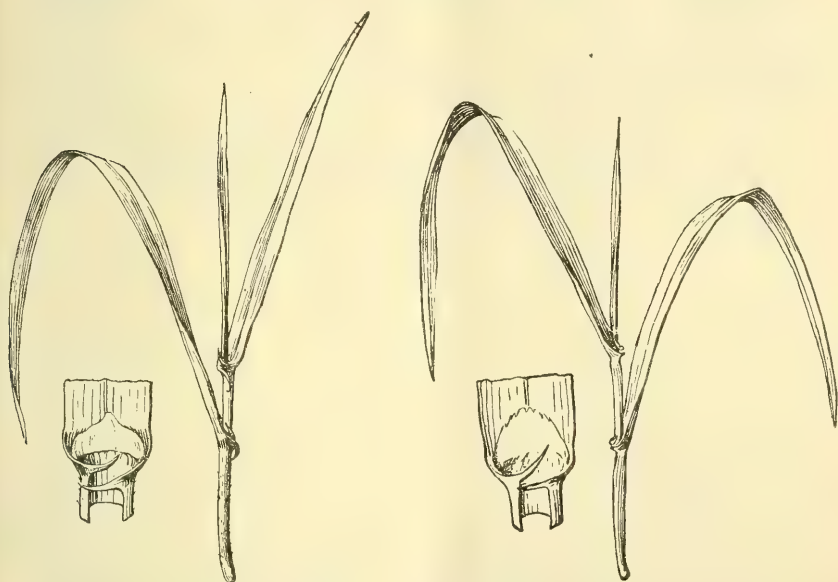
Collar broad, prominent, yellow, sometimes red, one side higher than the other, with large claws clasping the young shoot spirally; ligule membra-

FIG. 55.—Spelt (*Triticum spelta*).FIG. 56.—Wheat (*Triticum sativum*).

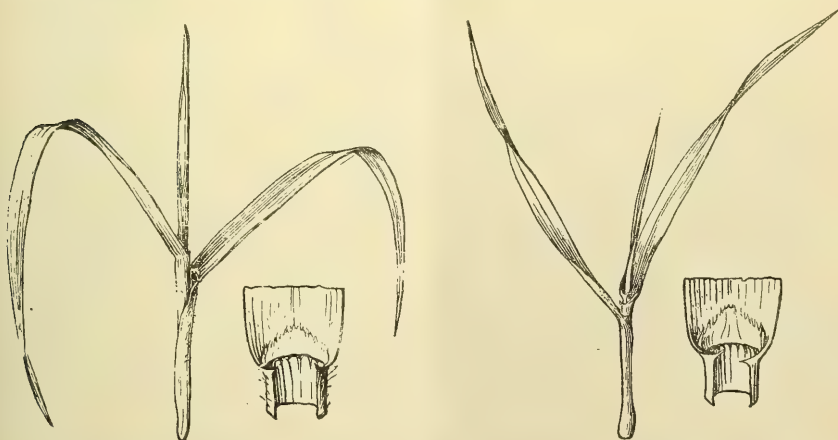
nous, medium long, acute, entire; sheaths sparsely hairy; blades broad at base, shorter than those of wheat, rough on upper surface, one-half inch wide, sharp pointed; nerves not prominent, covered with white specks when viewed under a lens.

54. Polish wheat (*Triticum polonicum*; fig. 58).

Collar broad, spiral, with claws, hairy on margins and claws; ligule long, acute, notched on top; sheaths not hairy; blades one-half inch wide, long, sharp pointed; nerves broad and prominent on upper surface.

FIG. 57.—Barley (*Hordeum sativum*).FIG. 58.—Polish wheat (*Triticum polonicum*).

It is difficult to find characters which will distinguish this grain from barley, although there is considerable difference in the appearance of the two when growing. The claws

FIG. 59.—Rye (*Secale cereale*).FIG. 60.—Durum wheat (*Triticum durum*).

of Polish wheat are more slender than those of barley and may have rudimentary hairs when viewed with a lens, while barley has none. The collar of Polish wheat is not so broad and prominent as that of barley.

55. Rye (*Secale cereale*; fig. 59).

Collar broad, not spiral, continuous, with fine, sharp claws barely overlapping; ligule short, truncate, lacerate; sheaths sometimes hairy; blades toothed on margins, hairy at base on upper side, sparsely hairy elsewhere, one-half inch wide, abrupt pointed.

The sheaths and blades are usually covered with a powdery bloom, which gives a pale bluish cast to this plant.

56. Durum wheat (*Triticum durum*; fig. 60).

Collar broader than that of common wheat, but not so noticeable as that of barley; claws small, free from hairs; ligule acute, thin, membranous, toothed, medium long; sheaths free from hairs; blades prominently nerved, soft, glabrous, one-half inch wide, abrupt pointed.

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LOGAN WALLER PAGE, Director



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February 16, 1917

IRRIGATION IN FLORIDA.

By F. W. STANLEY, *Irrigation Engineer.*

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HISTORY OF IRRIGATION IN FLORIDA.

The first attempts at irrigation on an extensive scale in Florida seem to have been made during the droughts of 1890 to 1893. Before that time the production of citrus crops was not highly systematized and little attention was paid to the intensive methods of agriculture which have developed rapidly in recent years.

Prior to the disastrous freeze of 1894-95 the center of the citrus industry was Marion County. The town of Citra was the largest shipping point in the State. Approximately 2,200 acres of orange groves had been planted in this section by 1894, of which about 500 acres were irrigated.

The freeze of February, 1895, followed a very severe one which occurred the preceding December. These two cold spells froze trees to the ground in nearly all the citrus sections of the State and were especially severe in Marion County. The blow to the citrus industry was so great that many of the farmers left the State, while the

majority of those who remained in the industry moved farther south, where the danger from extreme cold is not so serious. The financial depression that followed the freeze caused the abandonment of practically all the irrigation systems, and many of the owners took up the pipe and sold it for old iron. Only about 25 or 30 acres of irrigated groves remain in this section at present.

In the southern counties, where the effects of the freeze were not so disastrous (although very severe), the trees were cultivated and cared for and soon were bearing fruit. The period following the freeze was so favored with rainfall that most of the irrigation systems fell into disuse and many were taken up.

The excessive drought of 1906 revived interest in irrigation, however, and when this was followed by four more dry years many of the most skeptical installed irrigation plants.

The comparatively rainy seasons of the last three or four years have discouraged recent extensive development of irrigation in citrus groves, but the large development of the trucking industry has brought about a considerable extension of irrigation in that field.

ESTIMATE OF TOTAL IRRIGATED CROPS.

An accurate estimate of the total acreage of irrigated lands in the State is difficult to make. Many of the irrigation plants are miles from any others, while some of the territory containing a considerable percentage of irrigated lands would have to be surveyed very carefully to secure any accurate estimate.

Several methods were employed to secure a rough estimate of the acreage irrigated. Much of the State was covered by the writer in an automobile and estimates for each locality were obtained from the best-informed residents. Another source of information was several hundred inquiry cards sent out by the Department of Agriculture and returned by farmers who were practicing irrigation. These cards afforded a good index to the methods and costs of irrigation in the various sections, but were of little use as a general census, since only a small percentage of the plants was reported in this way. Valuable information was obtained from several of the prominent irrigation supply men of the State and from well-known irrigators, who gave estimates of local irrigated areas.

The acreages irrigated are estimated as follows:

Acreage of irrigated crops in Florida in 1915.

| | Acres. |
|------------------------------|---------|
| Irrigated truck crops: | |
| Surface irrigated..... | 12, 000 |
| Subirrigated..... | 2, 500 |
| Overhead spray..... | 3, 000 |
| Irrigated citrus groves..... | 8, 000 |
| Total | 25, 500 |

This estimate probably is fairly accurate and amounts to approximately 10 per cent of the area in grove and truck crops, the area in field crops being of small importance from an irrigation standpoint. Nearly 20 per cent of the truck crops is irrigated, as the total acreage of truck crops in the State is estimated at 91,000 acres. If watermelons and cantaloupes are not included in truck crops, approximately 25 per cent of the present acreage of truck crops is under irrigation.

The largest area of surface-irrigated lands within a restricted district lies in and near the Hastings potato section and equals about 10,000 acres. The remainder of the surface-irrigated lands is scattered; although there are about 1,000 acres irrigated in Manatee County, all within a few miles of the town of Palmetto. The next largest irrigated area is the Sanford district, which contains 1,600 to 2,000 acres of subirrigated lands. The irrigated groves are well scattered over the citrus section, the largest area within a restricted district being near Palmetto, Manatee County. The overhead-spray systems also are well distributed, although there are several trucking sections which contain several hundred acres under spray. The sections around Williston in Levy County, Bushnell in Sumter County, and Bartow in Polk County are the best known.

THE NEED OF IRRIGATION IN FLORIDA.

The condition making irrigation necessary in Florida is not the deficiency in annual rainfall, but its uneven distribution. Localities having a very heavy total rainfall are subject to heavy downpours at times, with long, rainless periods at other times. As crops are grown throughout the year, the distribution of the rainfall becomes of great importance. Truck crops are grown during the winter months—October to May—and require water during that period. Citrus fruits make their growth during the spring and summer months and must not be allowed to become too dry.

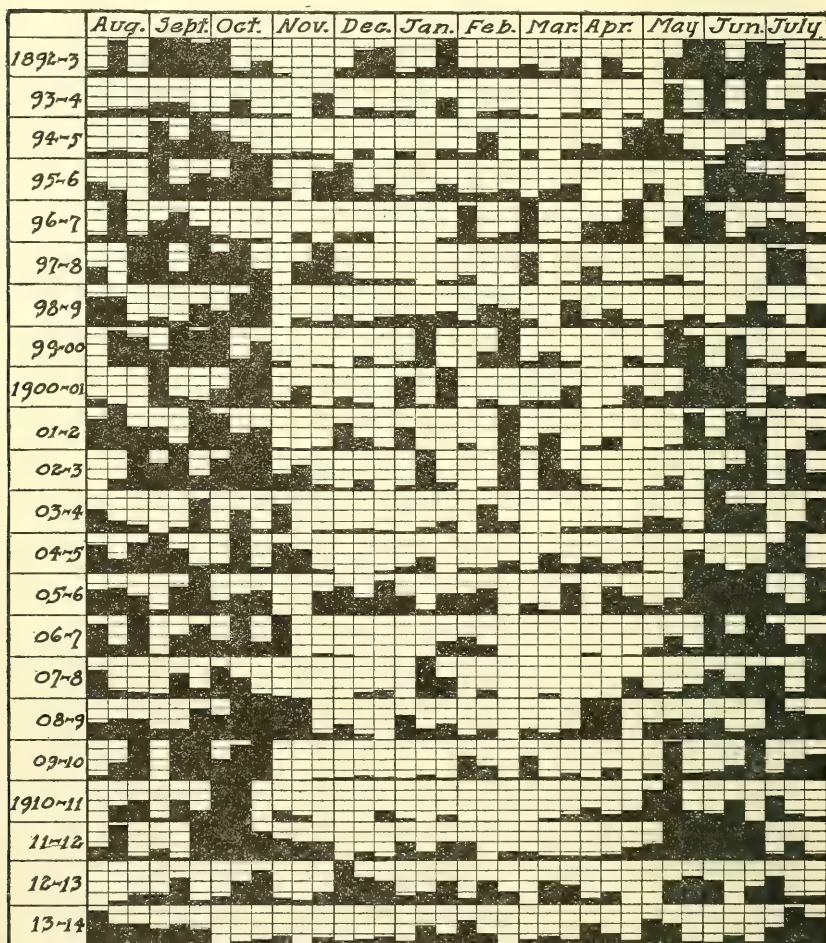
The mean annual rainfall at some of the Florida stations is as follows:

Rainfall in Florida.

| | Inches. |
|--------------------|---------|
| Pensacola | 56.25 |
| St. Augustine..... | 47.98 |
| Orlando..... | 51.02 |
| Tampa..... | 53.21 |
| Fort Myers..... | 52.19 |
| Hypoluxo | 63.20 |

These stations read from north to south, the two extremes, Pensacola and Hypoluxo, having the heaviest rainfall. The central portion of the State from St. Augustine to Tampa varies but little in total

annual rainfall, although its distribution varies considerably, as will be shown later. The distribution of the rainfall and the occurrence of droughts at various points in the State are shown by the accompanying diagrams (figs. 1-4). These charts are plotted from records kept by the United States Weather Bureau from 1892 to 1914, inclusive. The stations selected probably are as representative of the



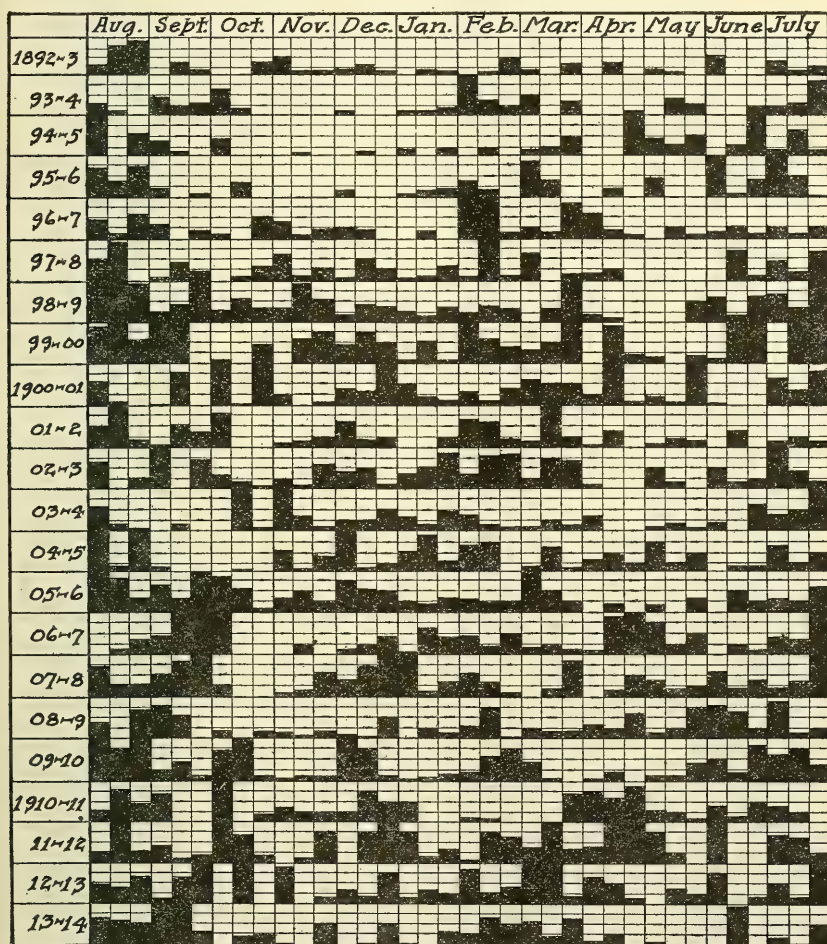
*F.K.L.

FIG. 1.—Chart showing rainfall of 4 inches or less for each 10-day period, 1892-1914, at Hypoluxo, Fla.

State as any that can be chosen without plotting a great number of points. Thus Pensacola is representative of the northwest counties, Orlando is fairly representative of the central peninsula section, Fort Myers should represent the southern west-coast section, and Hypoluxo the southern east-coast section.

It will be noticed on the charts that the spaces between vertical lines represent 10-day periods, while the black columns between these

lines represent the total rainfall during these periods, up to 4 inches. Many 10-day periods had more than 4 inches of rainfall, but the charts were made to show periods of rainfall rather than down-pours. In general, the rainy years show a preponderance of black spaces and the dry years a preponderance of white spaces.



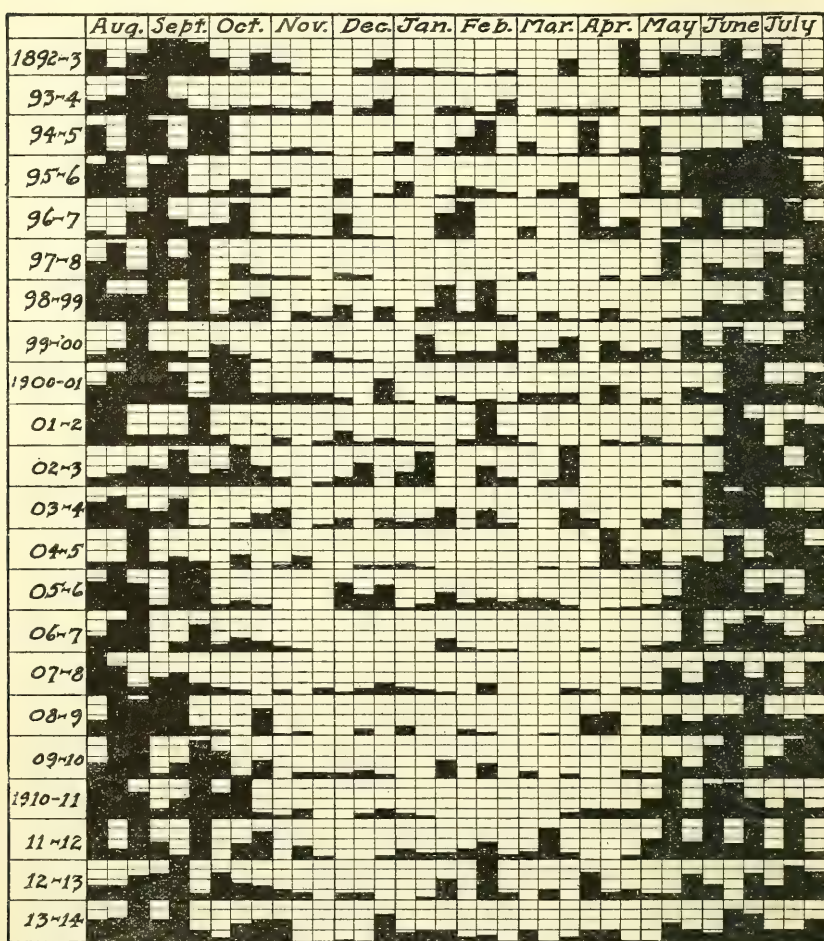
K.R.L.

FIG. 2.—Chart showing rainfall of 4 inches or less for each 10-day period, 1892-1914, at Pensacola, Fla.

The Hypoluxo chart (fig. 1) shows heavy rainfall in the summer months although that district is liable to long and severe droughts. Many of the black spaces in this chart represent considerably more

NOTE.—Although the rainfall charts do not indicate each shower the cumulative rainfall for each 10-day period totalling less than 4 inches can be read to within one-fifth of an inch; for example, see the Pensacola chart (fig. 2). The month of September, 1893, shows 1.8 inches rainfall the first 10 days; 1.0-inch the second 10-day period; and 1.2 inches the last period, or a total of 3 inches for the month. It will be seen that no rain fell in November of the same year and 4 inches or more fell in the first 10 days of February, 1894.

than 4 inches, and in some cases as much as 20 inches, of rain within a 10-day period. Hypoluxo is much more subject to these heavy downpours than are the other sections represented, although nearly every part of the State is exposed to excessive rainfall at some period of the year. These downpours usually take place from



F.R.L.

FIG. 3.—Chart showing rainfall of 4 inches or less for each 10-day period, 1892-1914, at Fort Myers, Fla.

June to October, October being the most subject to floods. Floods occur occasionally, however, in the winter and spring months and are apt to do much harm.

It will be noticed that the first great drought shown in the three charts (figs. 1, 3, and 4) representing the southern stations occurred in the season 1897-98. Fort Myers (see fig. 3) shows only light showers from the middle of October to the middle of May, while the

Orlando chart (fig. 4) shows very dry weather from the middle of October until the middle of July. The next drought of State-wide importance occurred in 1906-7, nine years after the one just mentioned. Fort Myers shows only small showers from the middle of

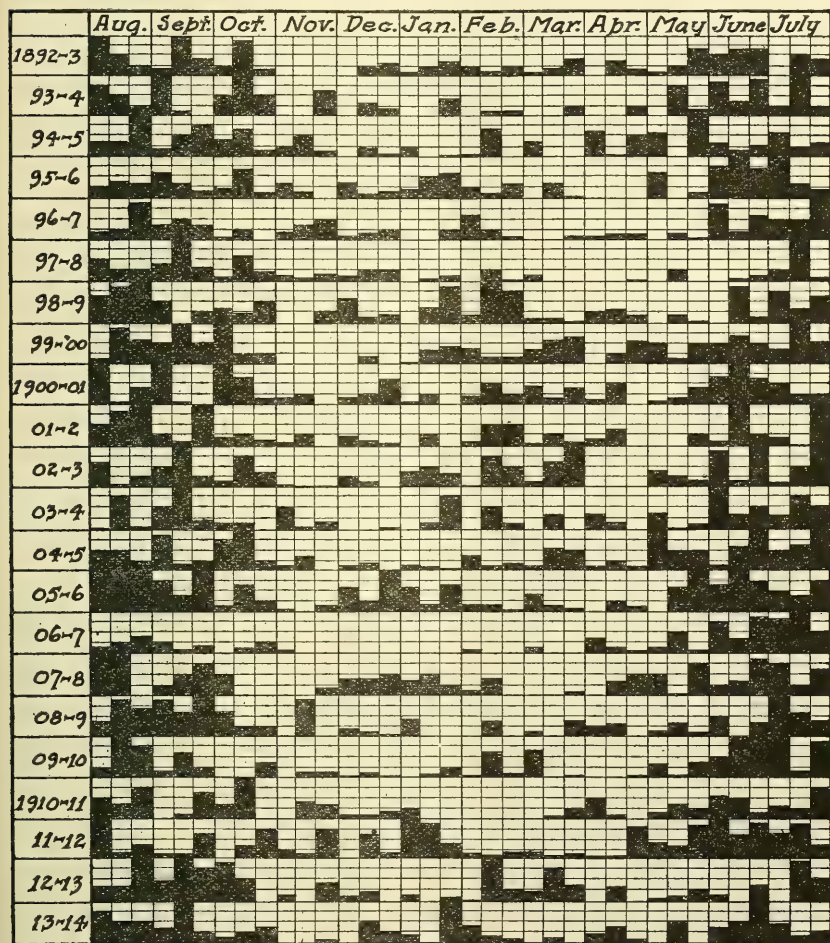


FIG. 4.—Chart showing rainfall of 4 inches or less for each 10-day period, 1892-1914, at Orlando, Fla.

September to the middle of May, a period of nine months. The Orlando chart shows dry weather from the first of August until the middle of June. The small rainfall shown in the charts for the spring and summer months for these years is not enough to be of lasting benefit, as the heat usually is excessive during these long droughts. The same drought, it will be noticed, occurred in Hypoxylon (see fig. 1) although much less severe, lasting from the first of

November to the middle of May. While there is seen to be a little rain in January and February, it presumably was not of lasting benefit.

The two droughts shown above are remembered throughout the State. It is asserted by the older residents that during both of them pine trees died from lack of water, and many of these dead trees are still standing as monuments to dry weather. The effect on the citrus industry also was serious. Although but few of the older trees were killed, nearly all lost their leaves and spring bloom; but orange and grapefruit trees have wonderful recuperative powers. When they have lost all their young fruit in the spring, they often will put forth a late bloom in June and mature this crop the next season. This is called the "June bloom" throughout the State, and is very common when heavy June rains follow a dry spring. The fruit from the June bloom often is inferior in quality and not so marketable.

There is a vast difference between the citrus crops and the truck crops in their need for water. The character of the soil enters largely into this difference and will be discussed in detail later. The average truck crop can not stand a drought of even short duration without serious loss. It is a common sight to see truck farmers irrigating their crops three or four days after a good rain, and in most cases truck crops are irrigated a dozen times before a citrus grove is considered in actual need of water.

Working in cooperation with the irrigation investigations of the Department of Agriculture, a vegetable grower of Hypoluxo has kept records of irrigation and rainfall from 1909 to 1913. His plant is fitted with a meter which records the exact amount of water used. His records also show the dates of each irrigation and the separate amounts of water used. The dates are now of interest in examination of the rainfall chart of Hypoluxo. (Fig. 1.) The amounts of water will be taken up under another heading.

The soil is sandy and representative of much of the sandy hammock along the coast and through other parts of Florida. The plants watered were mostly peppers and eggplant, although at times other crops were raised on the same ground. The soil may be taken as representative of much of the trucking soil of the State.

The season of 1909-10, although dry, as shown by the chart, was not excessively so, yet it was necessary to water the plants twenty times, as follows: twice in October, three times in November, twice in March, ten times in April, and three times in May. The early irrigations were for the benefit of the young settings, which needed water often. The spring irrigations were made to keep the plants in a flourishing condition, as peppers and eggplant bear continuously throughout the season if well cared for. It was necessary to irrigate only

nine times during the season of 1910-11, although it appears to have been as droughty as the previous season. This may have been due to a difference in the cropping, of which there is no record. There were three irrigations in October, three in January, two in February, and one in April. The season 1911-12 appears fairly well supplied with rainfall, judging from the chart, yet the plot was irrigated fifteen times as follows: five times in December, twice in February, five times in April, and three times in May. Fifteen irrigations were necessary in the season of 1912-13, as follows: three in October, one in November, one in December, three in January, two in February, three in April, and two in May. There are no records available for the last two years shown on the rainfall chart, but it is likely that fifteen irrigations, which is an average of the previous four years, would not be too high in either case.

Further study of these records will show that irrigation for truck crops may be practiced throughout every month in the growing season if there is a short period of dry weather, some of the irrigations apparently occurring even at the time of heavy rainfall. This may be due to the fact that several of the irrigations may have been made on successive days preceding a heavy rainfall, or the rainfall may have come in a number of small showers and been of little benefit to the plants. Examination of the entire chart would lead to the conclusion that Hypoluxo's rainfall was such as to call for 10 to 15 irrigations per year for truck crops for the last 22 years. If this is the case it can be seen readily that even more irrigation would be needed in Orlando and Fort Myers, assuming that the same crops were grown on the same type of soil. As a matter of fact, much of the sandy soil around Orlando calls for more water than does the soil around Hypoluxo, while some other crops require more water than do peppers and eggplant. On the other hand, many of the soils which are growing truck are lower and heavier than on this farm, and such truck crops as cabbage and melons need little water.

For citrus groves the dates of past irrigations are difficult to obtain, as no reliable data are at hand covering a long period. However, some records concerning an irrigated grove at Orlando are available and extend from the spring of 1909 to the fall of 1913. This plant was not completed until April, 1909, at which time the leaves of the trees were curling from lack of water. The grove was irrigated four times the year the plant was completed, once each in April, May, June, and July. The rainfall chart shows that water should have been applied several times before April, and the owner reports that he could have saved a great quantity of fruit if he had been ready to irrigate in February. This grove was irrigated once

in 1910 and twice in 1911, these irrigations coming in April and May. There was no irrigation in 1912, and the chart shows that probably none was needed. The years 1913 and 1914 were very well supplied with rainfall, although irrigation should have been practiced in the late spring of both years, and probably would have been if the engine had been in repair. The spring of 1913 was very dry in some parts of the State and was the cause of much loss through dropping of the newly formed fruit.

From a study of the records of the Florida State Horticultural Society,¹ it seems that there was considerable loss from drought in citrus groves in 1892-93 and 1893-94, and again in 1897-98. The proceedings of this society for the years 1895-96 and 1898-99 seem to be barren of discussion regarding irrigation affairs, but interest was again aroused during the long drought of 1906-7 and has continued to the present time, although the last three seasons have been favorable in some sections. A study of the rainfall charts makes apparent the reason for the ebb and flow of interest in irrigation.

Judging from the data in hand and a study of the rainfall charts, it would seem fair to estimate that about half the years (from 10 to 11 years in the last 22) are deficient in rainfall to such an extent as to make irrigation of citrus groves profitable. The Hypoluxo chart shows that the number of years in which irrigation was required is less than this average, probably varying from 5 to 7 in the last 22; in other words, 20 to 35 per cent of the years would call for irrigation. On the other hand, the number of years when irrigation was necessary is not of main consideration. The important points are how badly the trees need water when the dry years appear, and how much damage a drought causes, not only in immediate loss of fruit, but in permanent harm to the tree. These questions are answered in several ways, but nearly all answers agree that such years as 1897-98, 1906-7, and 1909-10 severely shock the health of the tree, and there is no doubt that irrigation at these times would insure a good crop of fruit when prices are high because of the lack of high-grade products.

RELATION OF SOIL TYPES TO IRRIGATION.

The relation of soil types to irrigation probably ranks second in importance to rainfall in determining irrigation needs. The writer has made a number of soil-moisture tests which bear directly on the needs of irrigation, but before discussing this subject it would be well to outline briefly the general types of soils as popularly known.

It is estimated by the State geologist, E. H. Sellards, that 75 per cent of the State originally was covered with pine forests. This

¹ Annual Proceedings of Florida State Horticultural Society.

accounts for the common use in Florida of the term "pine lands." While a large part of the original forests still stands, and there are many thousands of acres of uncultivated "cut-over" or stump lands, there are also thousands of acres of pine lands cultivated for all kinds of crops.

The rolling, or high pine lands, are very extensive, especially in the interior of the State. This land is used for the growing of citrus fruits as it is usually well drained, which seems to be necessary to the successful growth of most of the citrus fruits.

Associated with the high pine lands are the so-called high hammock lands, which differ from the high pine lands in that they bore originally a more or less dense growth of hardwood or deciduous trees. These types of lands usually have a deep topsoil underlain with a clay subsoil at a depth of from 4 to 6 feet, varying with the locality. The upper 6 inches of much of this soil is very dark in color, owing to organic matter, while the soil from the first foot to the clay appears to be almost pure sand, the organic matter decreasing rapidly with the depth. It is very necessary to bear this in mind in accounting for the behavior of water when irrigation by furrow methods is attempted.

Several types of pine lands locally designated under the general name of "flatwoods" are quite extensive in area. The two types best known, the "palmetto" and the "open," generally are very level, with poor natural drainage. The palmetto flatwoods originally were covered with pine and a dense undergrowth of saw palmetto. This type of land invariably has a hardpan underlying the surface at depths varying from 1 foot to 4 feet, and averaging about 2 feet. The open flatwoods may or may not have this hardpan.

These flatwood soils are very important from an irrigation standpoint, being used extensively in both the Hastings and Sanford districts for growing crops under irrigation. The part that this type of soil plays in irrigation will be taken up later.

Although the types of land described above cover the greater part of the State, several other types are cultivated and must be considered in a discussion of irrigation methods. The most noted exception to the sandy soils is the rocky soil of the lower east coast. This section is important in both trucking and citrus growing, although the soil is so rocky in some localities near Miami that large sums are expended in clearing away the rock, and trees frequently are set out in blasted holes. This rock is a limestone formation and forms a rim between the Everglades and the Atlantic Ocean.

Within the Everglades, at the southern end of the peninsula, there is a great area of peat and muck land. It has been estimated that there is between 2,000,000 and 4,000,000 acres. The depth of the

organic material varies from almost nothing to 14 feet, with the greatest depth in the lands adjacent to Lake Okeechobee in the central part of the glades. This area may be of importance from an irrigation standpoint after the drainage works are completed, but until that time little authentic information will be available. However, considerable areas of the Everglades are cultivated at the present time in narrow strips along the canals which have been constructed, and some of this land has been irrigated by both overhead-spray and surface methods. The light organic material dries out quite rapidly if the water plane is lowered sufficiently.

The State also includes a large acreage of muck lands along many of the large rivers and adjacent to the lakes. Only a small part of this land has been drained artificially and used for cultivation, although there are considerable areas under cultivation in isolated spots, as, for instance, along the St. Johns River in the Sanford district, and along the shores of Lake Apopka in Orange County. Probably the largest single drainage project in muck soils, excluding the Everglades, is at Felsmere, a few miles west of the Atlantic Ocean.

A type of soil closely allied to the muck soils is the so-called low hammock or "cabbage-palmetto hammock" lands.¹ These lands usually are very rich and require more or less drainage. Throughout the State many of the best trucking sections are located on this type of land. This soil may or may not be underlain with hardpan.

It will be noted that the few main types of soil discussed above are widely different in their characteristics. In these differences should be found one explanation for the diversified methods used in applying water to the crops. If the surface soil is very loose and sandy, as often is the case with the high pine lands, where the hardpan or clay stratum is well below the surface, the soil moisture probably will percolate below the root area. On the other hand, in the flatwoods where the hardpan is too close to the surface the soil has very little storage capacity, will flood easily, and in time of dry weather, will dry out rapidly. It is claimed by expert orange growers that a hardpan at a depth of 5 to 7 feet is the best condition for the growing of citrus fruits, while a hardpan at a depth of 2 to 3 feet often is regarded as an ideal condition for trucking. Although this is generally true, there are some very fine orange groves on the flatwood type of lands, and there are large acreages of citrus fruits in Lee and De Soto Counties, while many acres of truck are grown on the high pine and high hammock types of soil. Numerous fine groves and truck gardens flourish on the low hammock types all through the peninsula.

¹ The "cabbage-palmetto hammock" lands derived their name from the fact that their original growth contained a preponderance of cabbage palmetto, although there usually is a very dense undergrowth associated with the palmetto.

SOIL-MOISTURE TESTS.

The writer has made a number of soil-moisture determinations in citrus groves in and near Orlando and in the trucking sections of Sanford and Orlando. These tests were made in the spring of 1913 and throughout the season of 1913-14 for the purpose of determining the amount and location of available soil moisture at different times of the year and in the different types of soil.

Figure 5 represents the percentage of soil moisture¹ for the different dates throughout the season 1913-14, and at the same time shows the amounts of rainfall by three-day periods during the season. The tests for this chart were made in a citrus grove in Orlando. The top curve shows the average percentage of soil moisture for the first 6 feet of soil in an open, cultivated space that is not affected either by tree roots or by grass. The lower curve shows moisture content among full-grown orange trees, which have grown up from roots since the 1895 freeze. The vertical figures represent soil moisture in percentages and inches of rainfall, given in three-day periods. As an example illustrating the use of the chart, it will be noted that the total rainfall for the period between January 21 and January 24 was 3.8 inches. Again, note the effect of this rain on the soil moisture. On January 15 the soil in the grove showed only 3.9 per cent of soil moisture and the open space showed about 5.7 per cent. Immediately after the rain the average moisture content for the two sections was 9.5 per cent and 7.8 per cent, respectively, falling to 5 and 5.7 per cent within a few days. It will be noticed that in all cases showing a plentiful rainfall the two curves are close together, but that where the rainfall is deficient the curve representing the soil-moisture content in the grove drops very rapidly. The moisture in the open, rootless space, however, averages considerably higher at all times. The lower curve shows very plainly the effect of tree roots in absorbing the available soil moisture.

It is not possible to determine the exact percentage of soil moisture needed to keep the trees in good condition, as the citrus tree is very hardy and will not show wilt for a considerable period after the available moisture of the soil has been exhausted. The character of the soil also affects this, as some soils are more retentive of moisture than others. But there can be no doubt that the available supply of moisture is gone when the soil will run from the hand like dry sugar. This condition is found in most of the soils tested after the moisture content has fallen below 3 per cent. Judging from the curves in the

¹ The percentages of moisture referred to in this discussion are based on the ratio of the weight of dried samples to the difference in weight between the wet and dried samples. Each sample represents the moisture content at a certain depth in the grove or garden, and this is taken to be representative of a larger area.

TIME PLOTTED IN THREE-DAY PERIODS

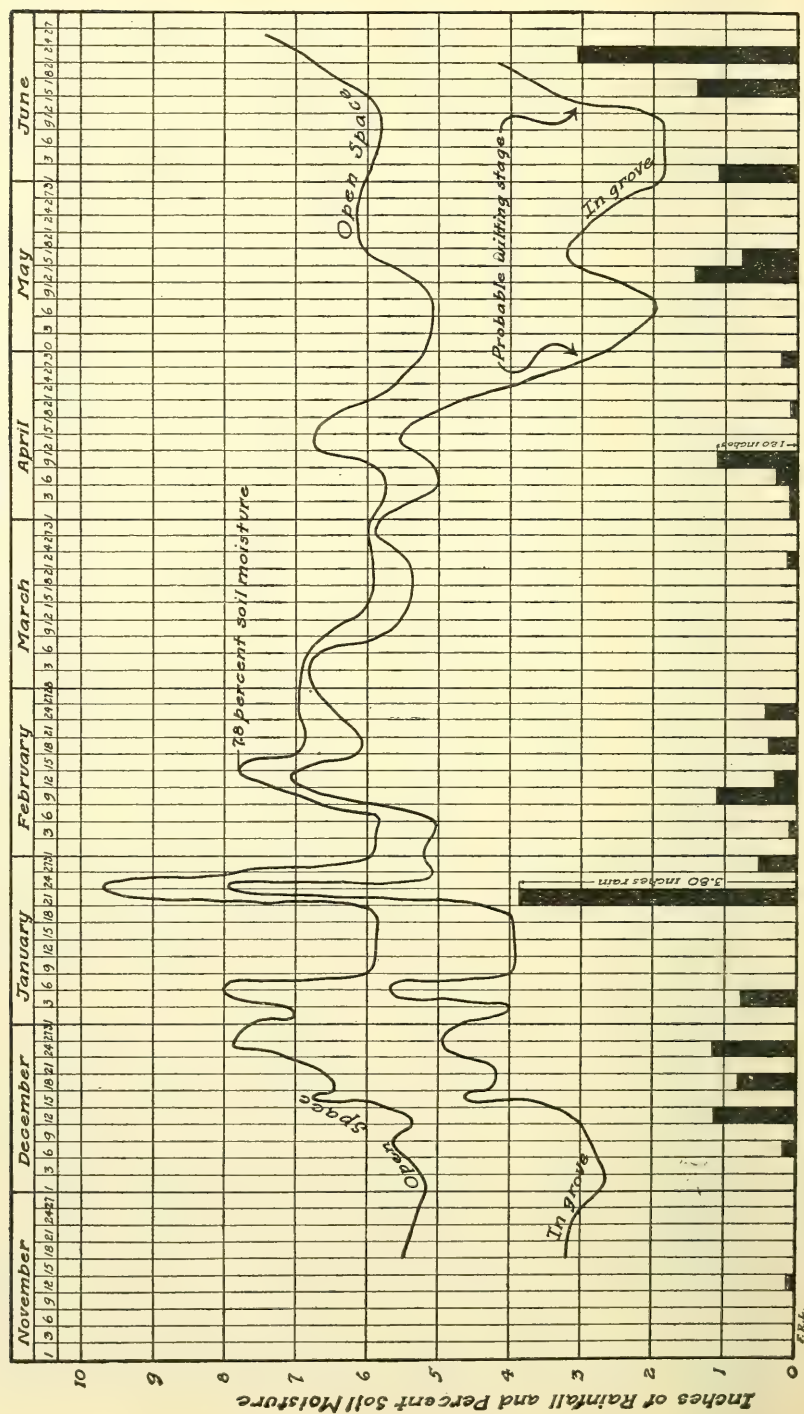


FIG. 5.—Curves showing effect of rainfall on soil moisture in sandy soil at Orlando, Fla., Nov. 15, to June 15, 1913-14.

chart, the soil in the grove was in this condition for the period from May 1 to June 9, with the exception of five days from May 12 to 16.

Other factors affecting the soil moisture which are not shown graphically are temperature and wind. February and March were cold and the evaporation was small, but April, May, and June were excessively hot. Many tests in the West show that the evaporation from an open, well-cultivated space is very small. With reference to the upper curve, it may, therefore, be assumed that the difference between the two curves shows approximately the effect of the groves upon evaporation, although the temperature in a grove is somewhat less than that in the open. However, the samples were taken as far away from the influence of shade as was possible while still well within the root area, and the trees were trimmed high, which permitted a good air current throughout.

This chart is especially valuable when used in connection with the rainfall charts (figs. 1-4). Taken together they give a clear idea as to soil-moisture conditions for the past 22 years, and from them it is possible to arrive at a fair average which should apply to the future as well as to the past. Space will not permit a thorough study of these problems, but from the charts it may be seen that there have been many periods in the past when the moisture content of the average orange grove has been below the 3 or 4 per cent which seems to be necessary for growth. It also may be seen that small amounts of rainfall in the warm spring months of April, May, and June are not of great importance, since the moisture soon disappears.

Figure 6 shows the effect of cultivation in a citrus grove. These tests were made in representative groves, and the curves show the average of a number of tests made at Maitland, Orlando, and Drennen Station, 4 miles south of Orlando. These borings were made at times of drought, most of the tests being made in May and June, 1914, at a time when the soil was very dry, as is shown in figure 5. The cultivated portions were kept in good condition throughout the season, a good dust mulch being preserved. The uncultivated portions were not disturbed at any time through the summer or winter. The soil, in some cases, was well packed, and in all cases it was covered with a heavy growth of grass and weeds, dead at the time the samples were taken. It would have been possible to keep the weeds and grass down, but this would not have represented true conditions, as grass and weeds grow in abundance where groves are not cultivated. The spaces designated in figure 5 as "open" were outside the radius of any tree roots. The curves for the grove show moisture content for full-grown orange trees. Soils, in all cases, were of the high-pine class.

The results shown by the curves need little comment. It is apparent that cultivation in the open spaces has had a marked effect

upon the soil moisture. The top curve shows good moisture content under the dust mulch, which is seen to be about 5 inches in depth, while the open, uncultivated space is seen to be very dry for the first 2 feet in depth. The curves for the cultivated groves show no such marked differences, although there is nearly 1 per cent more

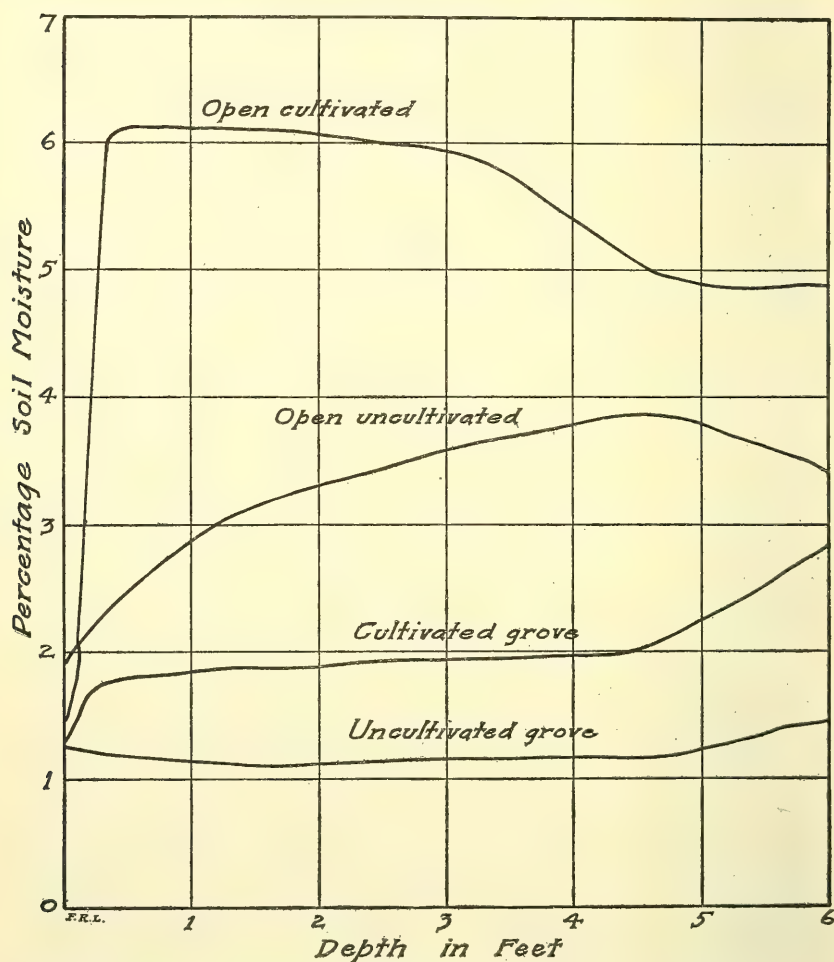


FIG. 6.—Curves showing effect of cultivation on soil moisture in citrus grove and open space at Orlando, Fla.

moisture in the cultivated grove; yet both curves are below the 2 per cent mark, which would show that both tracts were about as dry as could be. It is probable that the moisture represented by these two curves would appear to the eye to be about the same, the soil in both being dry enough to run freely between the fingers. The reader should be cautious, however, in drawing conclusions from these results. It can not be assumed, because there is so little differ-

ence in moisture content between the cultivated and noncultivated grove, that cultivation has done little good, as it is quite probable that the trees within the cultivated space have had the benefit of the moisture conserved by cultivation, which was lost through grass roots or evaporation in the uncultivated grove. Observation of the effects of cultivation shows that it will prevent wilt for some time after uncultivated groves are showing distress both in loss of fruit and by curling leaves. On the other hand, the moisture curves show conclusively that both cultivated and noncultivated groves have depleted their available moisture supply from the soil, which evidently can be supplied only by rain or irrigation. A great number of tests have proved this point beyond dispute, yet there are many growers in Florida who advocate that cultivation will take the place of irrigation. Scientific tests show that this can not be true in case of protracted drought, although it may be true for short periods of dry weather. In any case, it appears that it would pay to cultivate the groves during the dry weather if all possible moisture is to be conserved.

OTHER FACTORS DETERMINING THE NEED OF IRRIGATION.

The two factors treated above, rainfall and soil, doubtless are of primary importance in determining the need of irrigation in the State, yet there are a number of other factors that enter into the matter. Shallow-rooted crops, such as truck or small fruits, will suffer from drought much sooner than deep-rooted crops, such as orchards. The difference in the cropping also calls for a different type of irrigation system, as it is evident that the shallow-rooted crops, upon light soil subject to rapid drying, demand a system that will apply water rapidly and more often than is necessary for groves. The difference would be much more evident were it not for the fact that most of the vegetable crops are grown on low grounds which are not so subject to harm in dry weather.

The average field crops of Florida, as a rule, are not irrigated. There are two reasons for this: first, that most of the field crops either are grown in the northern counties where the rainfall is more evenly distributed, or in the southern counties after the truck crops are off, which usually is well toward the rainy season; and, second, that most of the field crops stand considerable drought and at the same time do not require such intensive cultivation as the truck crops or citrus fruits. The profits per acre usually are small compared with truck crops or citrus groves, and under ordinary conditions will not warrant an outlay for irrigation purposes.

Irrigation is used in some cases to prevent frost from injuring plants; in some citrus groves to combat insect pests. These problems will be treated later.

WATER SUPPLY AVAILABLE FOR IRRIGATION.

Practically every part of the State is well supplied with water for irrigation purposes, in the form of lakes, streams, or wells. The rivers are little used as an irrigation supply, either by means of diversion ditches or through the use of pumping plants, but the lakes and wells are used extensively both for irrigation purposes and for domestic supply.

The lakes are a constant surprise and delight to the new arrival, and are scattered from one end of the State to the other, varying from the size of a small pond to the huge Lake Okeechobee. The lands bordering many of the lakes offer promising sites for orange or grapefruit groves, since the lakes not only afford a water supply for irrigation but are a material aid in keeping up the temperature in times of cold waves. It would be difficult to approximate the number of groves that border lakes in the State, but a large percentage of the groves in Lake, Orange, and Polk Counties are so situated. The elevation of the groves above the surface of the lakes varies considerably in different sections, but there are few irrigation plants which elevate water more than 100 feet, while a fair average of them probably would show less than half this lift.

Where no lakes are available water usually is obtained from wells without much difficulty. The area in which flowing wells have been sunk is very extensive and includes much of the land lying below the 50-foot contour. The State geologist has prepared a map showing the artesian belt, and this map should be consulted if a newcomer is considering irrigation from flowing wells. In general, the area follows the east coast of Florida from Jacksonville to the Everglades, covers all the Everglades, then follows the west coast to a point a few miles above Tampa. This border varies in width, but as a rule does not extend many miles inland. Other areas yielding artesian flow follow in narrow strips along the St. Johns and the Kissimee Rivers, while there is another artesian belt on the mainland, bordering the Gulf from the Appalachicola River to the extreme western border of the State.

The depths of the flowing wells vary greatly throughout the State. Many of the wells around Jacksonville are more than 500 feet in depth, while near Hastings the wells are shallow, frequently being only about 125 feet deep. The wells in the Sanford district are shallow, often being less than 100 feet. The depth of those in the southern part of the State is very great, some wells near Palm Beach having been sunk 1,000 feet before a flow was obtained. The wells on the west coast, which furnish water by natural flow, also are of varying depths. The flowing wells in the Fort Myers district vary in depth from 400 to 800 feet, while a series of flowing wells in the

Manatee district probably averages 500 feet. Some of the wells in the Fort Myers and Manatee districts have a very heavy flow, registering as much as 20 pounds pressure when capped. One 6-inch well near Palatka, now used for irrigation, flows more than 1,000 gallons per minute at the well, and will force water to the second story of the house, which stands on an elevation some 10 or 15 feet above the well.

As the elevation of the ground surface increases the flowing artesian wells disappear. Much of the central portion of the State is in this higher area. The wells in the non-flowing artesian belt usually appear to be inexhaustible from a pumping standpoint. Many of the bored wells above the flowing artesian belt are used as drainage wells. These will take great quantities of water without materially affecting their own water levels. This fact is explained by geologists as due to the porous nature of the water-bearing limestone strata underlying the entire State.

Much water for irrigation is derived from driven wells, which usually draw on the surface supply. There are not many open dug wells, as the sandy character of the soil makes an open well difficult to manage. A few open wells in the Miami section, however, are dug in the limestone formation, and these supply water to a number of irrigation plants, some yielding large amounts of water.

DESCRIPTION OF IRRIGATION SYSTEMS IN USE IN FLORIDA.

The important types of irrigation practiced in Florida are: (1) subirrigation, (2) overhead spray, (3) grove irrigation, which includes many different systems, and (4) furrow irrigation, applicable both to truck crops and to citrus groves.

SYSTEMS FOR THE IRRIGATION OF TRUCK CROPS.

Sanford is located on Lake Monroe, in the central part of the peninsula, about 28 miles west of the Atlantic Ocean. The lake is formed by the widening out of St. Johns River, which is used for transportation purposes, and handles considerable freight between Sanford and Jacksonville. It will not accommodate the large ocean steamers, but will float good-sized river steamers. There also is direct railroad connection with the northern markets.

Practically all of the cultivated area in the Sanford district is devoted to the growing of winter vegetable crops for use in the northern markets. It also grows summer fodder crops for home use.

The soil, for the most part, is of the flatwoods type, although there is some low hammock in certain localities. Much of the land away from the river is practically level, although the general trend of the grades is toward the river. A considerable area adjacent to the river, however, has heavy grades, some of the lands falling several feet to

the hundred. The grades are uniform in the latter case, the contours running about parallel to the river's edge.

The surface soils of this flatwoods type generally are light and sandy, the percentage of sand increasing with the depth until the subsoil is reached. The upper 6 or 8 inches often is rich in organic matter and dark in color, but a large percentage of the soil between the first foot and the subsoil appears to be mostly sand of a whitish or yellowish tinge. The small areas of muck or hammock lands have deeper surface soils and more organic matter throughout. The sandy soils offer very little resistance to the rapid percolation of water in times of heavy rain.

Throughout the Sanford area there is a practically impervious subsoil underlying the surface at depths varying from 1 foot to 5 feet. This impervious substratum is sometimes composed of a clay, but usually is of a sort of sandstone which appears to be cemented together with a yellowish material apparently composed of organic materials containing considerable iron, and is very hard and nearly impervious. (See Pl. I, fig. 1.)

The water supply for irrigation use is obtained entirely from flowing wells which vary in depth from 65 to 200 feet, the shallower wells being located close to the river. It is reported that there are at least 1,000 flowing wells in this district, most of them being used wholly or partly for irrigation purposes, although a number may water private garden patches only. The cost of the wells varies with the size and depth. There are few wells in use, however, over 4 inches in diameter, while practically every farmer adopts the 2-inch size, which costs about \$1 per foot complete. One well will irrigate 2 to 5 acres, depending upon the character of the soil and the flow of the well. A good 2-inch well will flow 30 to 100 gallons per minute, the better flow usually being on the lower elevations. It is a common practice for the farmer to have a number of 2-inch wells scattered over his farm rather than to attempt to get larger wells with greater capacity. Many farmers having 15 to 20 acres under cultivation will have four to seven wells, while others will make one well water 5 to 10 acres. The advantage of more wells is considerable, as rapid irrigation is especially desirable at the time of setting plants and depends upon the amount of water available.

SUBIRRIGATION AS PRACTICED AT SANFORD.

The application of water is accomplished by the so-called subirrigation method. Briefly stated, this operation consists of running water through underground tile laid with open joints so that the water escapes at the joints and percolates through the ground, thus watering the plants in the course of time. In order to water the entire ground surface, the tiles are placed in parallel rows as close

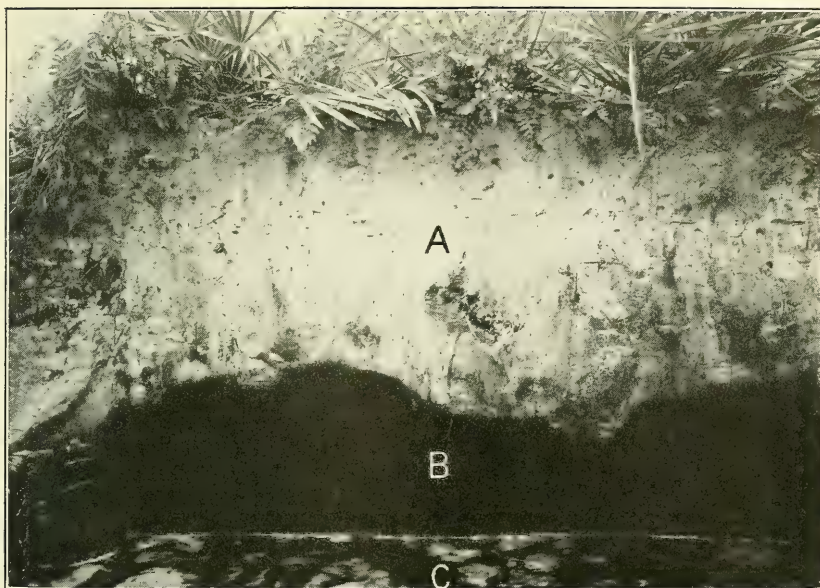


FIG. 1.—CROSS SECTION OF SOIL FORMATION IN SUBIRRIGATED SECTION, SANFORD, FLA.: A, LIGHT TOPSOIL; B, HARDPAN; C, WATER.



FIG. 2.—WATER-TIGHT MAIN AND STOP-BOX CONNECTION TO SUBIRRIGATION LATERALS, SANFORD, FLA.



FIG. 1.—SUBIRRIGATION LATERAL TILE LAID IN TRENCH BEFORE JOINTS ARE COVERED.



FIG. 2.—SUBIRRIGATION STOP POCKETS, SANFORD, FLA.



FIG. 3.—WATER SUPPLY AND TOOLS USED FOR SUBIRRIGATION, SANFORD, FLA.

together as experiment has shown to be necessary. In the Sanford district it has been found that irrigation is accomplished to best advantage when the tiles are placed 18 to 20 feet apart, although wider spacing is used in some cases. If the tiling is placed farther apart the irrigation will be uneven or will take too long. If the tiling is closer, the irrigation will be satisfactory, but the cost will be excessive.

The actual construction of a tile irrigation system requires considerable care and should be left to experienced hands. The following description of construction is taken from a report made to the Office of Public Roads and Rural Engineering by Milo B. Williams, irrigation engineer, who has had considerable experience in the construction of tile systems at Sanford:

The tile system consists of a water-tight main pipe feeding a series of open-jointed parallel laterals placed 16 to 18 inches below the surface. The mains are located on the highest side or on the ridges throughout the field, so that the laterals slope away from the mains at the proper depth. The mains are of 4 to 5 inch vitrified terra-cotta pipe, which is obtained in 2½-foot lengths, with a bell end. The joints are made water-tight with cement. A stop box is placed at the intersection of each lateral with the main. (Pl. I, fig. 2.) Holes are cut in the side of the pipe and a short length of 2-inch steel pipe is cemented into place to form a connection between the main and the head stop box, the laterals leading out from the stop box. This metal pipe also forms a neck into which wooden plugs may be inserted to control the flow of water. Where the main feeds two laterals leading in opposite directions from the same point the stop box is placed in the main line, with the laterals leading out from opposite sides of the box.

The laterals are built of 3-inch clay drain tile (Pl. II, fig. 1), which is obtained in 12-inch lengths. The pipe is laid with open joints by placing the short lengths end to end. A shovelful of sawdust or cinders is placed over each joint to prevent the fine sand from working into the line and stopping the pipe. The grades for the lateral trenches vary from a 1-inch to a 3-inch fall per 100 feet. These grades generally are obtained by turning the water into the trenches before the tile is laid, so that the digger can remove all irregularities from the bottom of the trench. The ordinary expense of the Sanford system, however, would appear to justify a more careful method of establishing and maintaining the grades. At the time the system is laid out it would be well to establish the grades of the laterals by means of a level in the hands of a competent surveyor, and they should be maintained throughout construction. Laterals are spaced 18 to 24 feet apart, but the shorter distance has proved the more satisfactory.

Stop pockets are placed in the lateral lines at intervals of 100 to 400 feet for the purpose of checking the water in the laterals and thus securing a small pressure in the lines above the pockets. When pockets are used for this purpose a weir division wall is inserted near the inlet side containing two metal-lined openings (Pl. II, fig. 2), one a 3-inch hole on a level with the tiles entering and leaving the box and the other a 1-inch hole about 6 inches higher. When the water is not to be held in the pipe line above a box the lower hole is left open, so that the water can pass down the line freely. When the water is to be held up the lower hole may be plugged, raising the water to the upper hole, or both may be plugged, causing the water to rise until it flows over the top of the weir wall into the next section of the lateral. The weir wall is placed

nearer the inlet side of the box, making the chamber on the outlet side large enough to admit the hand easily to operate the plugs. For this purpose cypress plugs are often used. One of these consists of a large hollow plug fitted to the opening and a smaller solid plug which fits the hole in the larger plug. By this arrangement different sized streams can be obtained. The plugs often become water-soaked, making it difficult to remove them. Sliding galvanized-iron gates would be preferable.

The tools used in excavating and installing the tile are shown in figure 3 of Plate II. The mattock and ax are used for cutting the roots in the newly cleared land. The wide irrigation shovel is used for removing the topsoil and the curved adjustable shovel for cleaning out and forming the bottoms of the trenches.

The cost of the Sanford tile system ranges from \$100 to \$125 per acre, not including the water supply or drainage outlet from the field.

In the operation of the Sanford system water is turned into the main feed pipes and divided among a number of laterals by operating the intake plugs. The plugs in each pocket are adjusted so that the water will be backed up in certain sections and held there until the moisture meets between the tile lines. The water issues from the tile joints into the porous sandy subsoil and follows along on top of the impervious substratum until the surface-soil area is underlain with a sheet of water. If irrigation continues after this state has been reached the water will soon show on the surface.

Irrigation is begun when the first winter crops are planted in the fall. The ground is completely saturated to the surface to settle the young plants into place and give them a start. The common practice is to irrigate every 10 days to 2 weeks during the growth of the crop, depending upon the rains which occasionally occur during the winter season. Celery is irrigated 24 hours before cutting. This is thought to swell the plants and make them brighter and heavier.

The length of time required to saturate the Sanford soils varies greatly on the different farms. Some farmers use a large head from a number of wells, forcing the water into both ends of level laterals, thus causing saturation within a few hours. Others use smaller amounts of water and take 12 to 48 hours to irrigate. The amount of moisture contained in the soil prior to irrigation and the depth to hardpan determine materially the length of time necessary for saturation. It also takes longer to subirrigate a field on which a cover crop has been turned. Likewise, a soil finely pulverized is slower to irrigate than one that has not been cultivated.

Overirrigation is a common practice, and probably is more expensive than is commonly realized. On opening the tile lines to drain off the excess water large quantities of the fertilizing constituents applied in commercial fertilizers are carried away. This has taught the farmers in this section the need of applying fertilizers immediately following a heavy rain.

There are special cases about Sanford deserving of mention which have not been touched upon in the above discussion. Systems for the subirrigation of the fields adjacent to the river which have heavy grades should be laid out somewhat differently from those described above. If the mains were laid on the high side of the field and the laterals allowed to run down the slope having a grade of several feet per hundred, the water would not have sufficient opportunity to perform its task of irrigating the ground between the lines. In such a

situation the main line should run down the steep slope while the lateral should lead off perpendicularly or nearly so, following approximately the contours and having a very slight grade, as in the case of the level grounds.

Instead of a main line of terra-cotta pipe some farmers use an open trough or flume, letting water into the laterals by removing wooden plugs from the side of the flume and damming the water in the flume by check gates. When this method is used water does not percolate from both sides of the tile lines but runs one way only, or down the grade from one lateral to the other. This method, while used in other parts of Florida as well as at Sanford, is not so satisfactory in very dry weather as is the subirrigation of the level lands, some of the farmers having great difficulty in getting the water to the surface.

Another special method used to some extent in Sanford is irrigation without the use of a head main feed line. In this case the lateral tiles are laid perfectly level and are fed from an open ditch which also serves as the waste or drainage ditch in times of excessive rains. This method is somewhat of a makeshift, but works very well, and can be used for a while in this form when the farmer can not afford a heavier outlay. Sometimes the farmer will use this method and lay the tiling double distance, filling in the additional lines after he has grown a crop. The double spacing does not work so well for irrigation but will answer as a temporary expedient and at the same time drain the land, which in many cases probably is of more importance than the irrigation.

Concrete tile was used almost exclusively for laterals in the early development of Sanford subirrigation. Recently, however, concrete tile has been mostly replaced by burned clay tile, as the concrete broke down after having been in the ground a few years. The disintegration of the tile probably was due to the use of materials unadapted to the making of a good concrete and to improper methods of manufacturing and curing the product. Cheapness was sought at the expense of quality, and a very porous tile was produced which gave great opportunity for soil acids to attack the structure.

The most necessary condition for successful subirrigation is a porous surface soil overlying an impervious substratum, which is the formation found in the Sanford section, as shown by Plate I, figure 1. The topsoil is a porous, light-colored sand, while the subsoil is a dark-colored hardpan which holds the water until it has spread laterally through the sandy topsoil. If subirrigation of high pine land with a clay subsoil 8 to 10 feet below the surface is attempted, the chances are that water could be run in the tile a month without any appreciable effect on the surface soil. Several attempts have been made

to subirrigate lands of such type near Orlando, but in every case complete failure has followed. There have been also several attempts to subirrigate the heavy clay loams of Alabama, but with most disheartening results. The causes of failure are obvious in every case when the nature of subirrigation is considered. In the attempts made near Orlando the water was lost in the depths below the surface soil and would have had to fill up all the soil above the clay substratum before surface irrigation could take place. In the Alabama installations the clay surface soils were water-logged for a distance of a foot or two on either side of the tile, the soil beyond being perfectly dry.

In the Sanford district, however, the distribution of the water is not impeded by heavy soils. There the action of the water during subirrigation has been studied carefully with the aid of a soil-sampling apparatus. These tests show that the irrigation of the surface soils is not due so much to the action of capillarity as to the simple process of filling up the soils with water. Tests taken at the time of irrigation show that the soil reaches the saturation point 6 inches under the ground surface before the surface soils are irrigated sufficiently. It also is common to find free water standing in the soils at 1-foot depths when the plants are in need of irrigation. These tests, along with many others, show conclusively the nature of subirrigation.

It is evident that this system of irrigation requires large quantities of water, and consequently subirrigation under soil conditions similar to those at Sanford is not an economical method where the water has to be pumped. Nevertheless, it is common for the uninitiated to regard this method with favor on account of its supposed saving of water. The large quantity of water needed is no particular drawback to the Sanford farmer because the nature of the water supply assures him an unlimited quantity at no operating cost.

A comparatively even ground surface, or a uniform slope, is required for successful subirrigation. If the ground is uneven the low places will become flooded while the high knolls will not be irrigated sufficiently.

Another factor in the successful operation of a subirrigation system is the correct kind of cropping. It has been stated that the Sanford district depends almost entirely on garden products. These crops invariably are shallow-rooted, most of the plant roots feeding within 6 inches of the surface. These, being annual plants, do not have an extensive root system. It has been demonstrated in the West that the subirrigation of trees is a failure on account of the stopping up of the tile by tree roots. This is especially true if the soil is rich in plant food to the depth of the tiling. On the other hand, there are records of successful subirrigation of citrus groves through tile sys-

tems in Florida, but in such cases it is possible that the water plane stood above the tiling for long periods, thus preventing the entrance of tree roots, as the roots of most cultivated trees will not penetrate below the level of the usual water plane.

There are several groves near Terra Ceia that are subirrigated and at least one grove near Palatka. At the present time these systems are working well, and are especially valuable from a drainage standpoint. As these installations are new it can not be determined how long they will withstand clogging by the tree roots. The subsoil surrounding the tile may be of such character as to keep roots away from the tile or the ground water may be high enough to discourage deep rooting. Still there is considerable danger of clogging if the ground water should be lowered by protracted drought or by artificial drainage on a large scale.

A common rotation of crops in the Sanford trucking district is as follows: first, lettuce is planted about September 1 and harvested about the middle of October. This is followed by celery, which should be harvested by February. Cucumbers may follow immediately and should be off the ground by the first week in May. Corn then can be planted and harvested in August. There still remains enough time to grow a crop of native hay before the time to plant lettuce again.

Many of the farmers follow an entirely different schedule, although most of them plant celery. Some plant celery in October and get two crops, the last crop being harvested in July. Others plant beans, cabbage, cauliflower, and various other vegetable crops, while still others plant a considerable acreage of potatoes. The winter truck crops are shipped to the northern markets, while the corn and hay crops usually are consumed at home.

It has been stated that the cost of tiling averages \$100 to \$125 per acre. This would be a heavy outlay for many crops, but when the total cost of equipping land and the annual expense of growing a celery crop is considered, the cost of irrigation does not seem exorbitant since the cost of equipment, outside of irrigation, is about \$450 per acre.

It should be emphasized that the Sanford subirrigation method serves also for drainage—entirely, in fact, for some crops. This is true especially for the summer cropping during the rainy season and frequently during heavy rains in the winter season. There are some disadvantages in having subirrigation and drainage systems combined, one being the large loss resulting from the draining away of expensive fertilizers; and another, the need of saturating the soil in order to get enough moisture at the surface. Even if other methods of irrigation were used, however, it would be necessary to have drainage systems installed to take care of excess water, and when it

is considered that the maintenance and operation are at an absolute minimum, it may be seen that the Sanford system of irrigation is satisfactory where conditions discussed above are favorable.

OTHER FORMS OF SUBIRRIGATION IN FLORIDA.

Several other localities use the tile systems for irrigation and drainage. Several hundred acres in the Manatee trucking sections are irrigated by this method, as are about 200 acres along the shores of Lake Apopka in Orange County.

Most of the tiling in these localities is similar to the systems described for Sanford, although there are exceptions. Some of the Manatee farmers use boards nailed in V-form instead of tiling. This is done in soft, springy lands where it is hard to keep tiling in alignment. It is doubtful if boards should be used even in such soft ground, and a common practice among drainage men is to lay ordinary clay tiling upon a single board placed in the bottom of the trench where the soil conditions are not favorable for tiling alone. The boards will rot out in about 10 years, while good tiling will last much longer, although it needs to be cleaned out occasionally.

The contour methods of subirrigation are practiced mostly along Lake Apopka, where the grades are too steep for the ordinary methods. Much of the trucking section here is in a narrow strip along the lake and some of the grades are quite steep, the land having a fall of several feet per hundred. Flowing wells are obtained at the lower levels on most of the farms, but they will not force the water to the top of the main, consequently it is common to install a small engine and low-pressure pump to act as a booster.

There are also isolated cases where there is no impervious substratum of hardpan to permit successful subirrigation. Such farms have a water plane standing within 3 or 4 feet of the ground surface and this saturated soil seems to act as a hardpan, preventing the loss of irrigation water. These instances prove conclusively, in the writer's opinion, that capillary attraction does not play an all-important part in the subirrigation of the sandy soils of Florida, for were this the case it would not be necessary to irrigate garden products when the soil 3 feet below the surface is saturated.

OPEN-DITCH SUBIRRIGATION AT HASTINGS.

Another method of subirrigation is that practiced in the potato district near Hastings. This is the largest irrigated area in the State, consisting of about 10,000 acres, of which 7,000 acres are in St. Johns County and 3,000 in Putnam County, all within the so-called Hastings district. Probably two-thirds of the potato crop in this territory is irrigated, practically all by the open-ditch method.

This section is very similar to the Sanford trucking district, both as to its soil conditions and its water supply. The ground surface in general is very level and the soil is of the flatwoods variety, interspersed with patches of low hammock lands. The highest elevation is about 17 feet above sea level, the average being about 10 feet. The potato lands are underlain with an impervious stratum or hardpan at depths varying from 20 inches to 5 feet.

The water supply is from flowing artesian wells (Pl. III, fig. 1), the average depth of which is about 200 feet. Some of the wells give a good flow at 110 feet, while others are nearly 400 feet deep. Most of them are 4 inches in diameter; the diameter of the average Sanford well is 2 inches. A good 4-inch well will supply about 300 gallons per minute. The cost of the wells increases with the depth, the average cost being about \$200 to \$300, or \$1.50 to \$2 per foot, complete.

In most cases water is applied to the crops through open field ditches placed in parallel rows 30 to 40 feet apart. (Pl. III, fig. 2.) These ditches are fed by a main ditch which runs at right angles to them. The dimensions of this vary somewhat, but it usually is about 2 feet on the bottom, $1\frac{1}{2}$ to 2 feet deep, and 7 to 10 feet wide on the top. The slope often is gradual enough to accommodate a row of potatoes along the banks. The head ditch in the average farm is a partnership affair running along the road, and is used as a general drainage ditch when necessary.

The water runs from flowing wells into the main head ditch, from which it is led into the field ditch. The water is controlled from the main to the laterals by simple wooden gates, or, in some cases, by temporary dirt embankments thrown up with a shovel. As at Sanford, the grades are very slight and the head of water often is relied upon to force a flow. The process of irrigation consists of filling the field ditches and keeping them so until the soil between them has become subirrigated. The action is essentially the same as that at Sanford, the open ditches merely taking the place of the underground tile.

The amount of water needed per irrigation by this system and the time required depend upon the amount of moisture in the soil. Generally a 4-inch well flowing 300 gallons per minute will irrigate 40 acres. In times of protracted drought the well is run continuously, one well taking care of 40 acres. The need for one 4-inch well on every 40-acre piece is accepted generally. If the flow is 300 gallons per minute, this means a duty of water of $7\frac{1}{2}$ gallons per minute per acre. This is not far from the amount allowed for some of the irrigation systems of the West. The time of irrigation depends upon the rainfall. No irrigation is needed in some years, while in others water is required during a large part of the growing season.

The cost per acre of a system for the irrigation of potatoes is exceedingly low. This is worthy of notice, as the average cost of irrigation in Florida for many of the systems is very high. An allowance of \$300 as the cost of a well to water 40 acres would mean an expenditure of only \$7.50 per acre. The field ditches are cheaply constructed, and part of their cost may be charged properly to drainage. The cost of operation and maintenance is practically nothing for an average-sized field, as the farmer can care for the irrigation while engaged in other duties.

The most serious disadvantage of this system is the waste of land due to the open ditches in the field. These ditches, which are a continual nuisance in cultivating the field, also harbor weeds. It is doubtful, however, if it would be a profitable investment to tile the lands and do away with the ditches, although some tiling is being installed. First cost is an important item to most farmers, and the waste of a little land is not a very serious matter in this section where land is cheap and uncleared land abundant.

OVERHEAD-SPRAY SYSTEMS.

Overhead pipes, bearing nozzles or upright pipe with revolving heads, are used extensively in the State. It has been estimated that 3,000 acres are irrigated in Florida by some form of overhead spray.

The spray irrigation plants probably are more widely scattered over the State than those of any other type. There are plants in Gadsden County, in the northern section of the State, and others of all sizes and descriptions in nearly all the intervening counties down to the southern part of Dade County, on the southernmost tip of the peninsula.

Several localities are supplied with a considerable number of spray-irrigation systems, the largest area being in Polk County around Barstow and Fort Meade. There is also an important spray-irrigation center in Sumter County around Bushnell and Webster, and in Levy County around Williston. Several other sections likewise are represented, a considerable area being on the lower east coast around Miami. Some of these plants will be described in detail and an attempt made to present the important problems in each case.

The most common type of overhead-irrigation system is of comparatively recent invention. It will be called the overhead-pipe system in this bulletin. In this system water is distributed (Pl. IV, fig. 1) by forcing it under pressure through small brass nozzles, which are set 3 to 4 feet apart in carefully aligned elevated pipe. The pipe bearing the nozzles is laid 6 to 7 feet above the ground on posts set in straight lines about 15 to 20 feet apart. The overhead pipe is so constructed that it may be rolled in bearings by means of



FIG. 1.—FLOWING WELL AT HASTINGS, FLA., USED FOR SUBIRRIGATION.



FIG. 2.—SUBIRRIGATION FROM OPEN DITCH AT HASTINGS, FLA.



FIG. 1.—OVERHEAD-PIPE IRRIGATION SYSTEM, SHOWING PIPE LINES SUPPORTED ON POSTS.

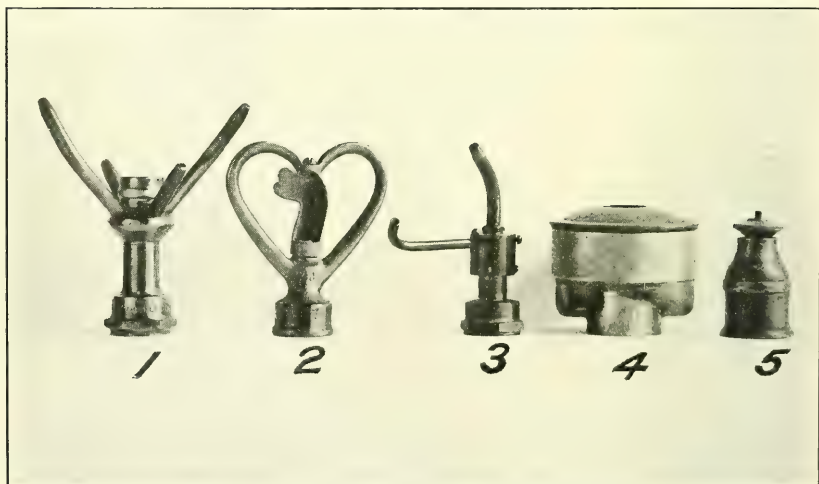


FIG. 2.—COMMON TYPES OF SPRAY NOZZLES USED FOR IRRIGATION IN FLORIDA.

a turning union. Thus when the pipe is turned to any one position every nozzle in it will assume the same angle with the horizontal. It is possible to turn, from one end, a pipe 700 feet long bearing 200 nozzles. The pipe lines usually are placed 50 feet apart, so that the nozzles in each line will throw water 25 feet on each side of the pipe. Each of these overhead-pipe lines is attached to the main supply pipe, the latter, in turn, being connected with a pumping outfit.

Several patented appliances are used in this system, two of the most important being the nozzles and the turning unions. The nozzles are small, $\frac{1}{2}$ to $\frac{1}{4}$ inch in length, with an outside diameter seldom larger than a lead pencil. The aperture for letting out the water usually is about the size of an ordinary pin. Each nozzle contains an outside thread which enables it to be screwed into a drilled and threaded hole in the pipe. The water is forced through this miniature nozzle at a pressure of 30 to 40 pounds per square inch, throwing a stream of water 25 feet from the pipe if the angle of the nozzle with the horizontal is approximately 45 degrees. When several hundred feet of pipe bearing a number of nozzles are in use and each nozzle is throwing water 25 feet from the pipe a continuous strip of land will be watered. When it is desired to water another strip, the pipe is turned. It usually is necessary to turn the pipe through six or seven positions in order to water the 50-foot strip covered by one line. As a rule, this pipe is turned by hand, although there are several appliances on the market which turn the lines automatically.

The design of the pipe lines is an important item. The lateral pipe lines bearing the nozzles are of constant size for a given length. Tables have been prepared by dealers in irrigation supplies which give the sizes of pipe necessary for different lengths. In general, it is customary to begin at the lower end with $\frac{3}{4}$ -inch pipe; run this for about 100 feet, then increase to 1-inch pipe, run this for another 100 to 150 feet, and so on until 2-inch pipe is reached.

TABLE 1.—*Sizes of pipe for outdoor nozzle lines.*

[Calculated on outdoor nozzles placed 4 feet apart. If the nozzles are closer together larger pipe must be used.]

| Nozzle No. | Length of line. | $\frac{3}{4}$ -inch pipe. | 1-inch pipe. | $1\frac{1}{4}$ -inch pipe. | $1\frac{1}{2}$ -inch pipe. | 2-inch pipe. |
|--|-----------------|---------------------------|--------------|----------------------------|----------------------------|--------------|
| | <i>Feet.</i> | <i>Feet.</i> | <i>Feet.</i> | <i>Feet.</i> | <i>Feet.</i> | <i>Feet.</i> |
| No. 2 outdoor, 4 feet apart, or No. 1, 3 feet apart..... | 150 | 115 | 35 | ----- | ----- | ----- |
| | 200 | 100 | 100 | ----- | ----- | ----- |
| | 250 | 90 | 100 | 60 | ----- | ----- |
| | 300 | 90 | 100 | 110 | ----- | ----- |
| | 400 | 80 | 100 | 120 | 100 | ----- |
| | 500 | 75 | 100 | 120 | 120 | 85 |
| | 600 | 75 | 100 | 120 | 120 | 185 |

The size of main needed depends on the number of laterals it is required to operate at once, or, in other words, the acreage that is to be watered at one time.

Table 2 gives sizes of mains needed for different quantities of water, according to the acreage to be watered. The data in this table are of a general nature and may be modified to suit the specific conditions. By following the sizes of the pipe as indicated below there will be ample capacity for the successful operation of the system under all conditions encountered.

TABLE 2.—*Size of pipe for main supply line.*

| Discharge in gallons per minute. | Length of line in feet. | | | | | | | |
|----------------------------------|-------------------------|----------------|----------------|----------------|----------------|----------------|----------------|----------------|
| | 50 | 100 | 200 | 300 | 400 | 500 | 600 | 700 |
| | <i>Inches.</i> | <i>Inches.</i> | <i>Inches.</i> | <i>Inches.</i> | <i>Inches.</i> | <i>Inches.</i> | <i>Inches.</i> | <i>Inches.</i> |
| 30..... | 1½ | 2 | 2 | 2 | 2½ | 2½ | 2½ | 2½ |
| 75..... | 2 | 2½ | 2½ | 2½ | 3 | 3 | 3 | 3 |
| 100..... | 2½ | 2½ | 3 | 3 | 3 | 3½ | 3½ | 3½ |
| 150..... | 2½ | 3 | 3 | 3½ | 3½ | 3½ | 4 | 4 |
| 200..... | 3 | 3½ | 3½ | 4 | 4 | 4 | 4 | 4 |
| 300..... | 3½ | 3½ | 4 | 4 | 4 | 4 | 5 | 5 |
| 400..... | 4 | 4 | 4 | 5 | 5 | 5 | 5 | 6 |
| 500..... | 4 | 5 | 5 | 5 | 6 | 6 | 6 | 6 |

The above system is in operation on about 150 acres within a few miles of Williston, in the north-central part of the State. The plants are mostly small, usually irrigating not more than 10 acres, one plant which irrigates 55 acres being an exception. The water supply for this plant is obtained from a bored well about 100 feet in depth, and is pumped from the well into the main by a steam duplex pump with rated capacity of 700 gallons per minute, operated by a 70-horsepower steam engine. The plant is designed to irrigate about 20 acres at one time, which requires a 7-inch main at the start. This is reduced to a 5-inch main at the end of the field, and might be reduced still more but for the fact that this pipe supplies water also to about 60 acres of surface-irrigated land. Much of the pipe is second-hand, and there is no record of its cost, but it is estimated that to replace it with new galvanized pipe would cost about \$100 per acre for the field laterals and an additional \$150 per acre for the pump, engine, and the main. This would mean a total cost of \$250 per acre, or approximately \$13,750 for the system, complete. The owner burns wood, which is plentiful in this section. He estimates that with wood he can operate his plant for 24 hours, the wood costing only \$1.25 per cord. This is exceedingly low for operating expenses. The plant is run day and night continuously when it is in operation at all, owing to the difficulty of getting up steam every day; also because irrigation at night is found to have a number of advantages, such as smaller loss by evaporation and prevention of scald.

Cucumbers are the principal crop grown in the Williston section. There is much controversy concerning the effect of spray irrigation upon this crop, although all the systems were installed for the purpose of watering cucumbers. Some of the farmers owning irrigation plants are very much opposed to spraying cucumbers, claiming that the water applied on the leaves by the spray systems materially increases blight or rust. Many owners are willing to sell their systems at a great sacrifice. Others claim that blight is as troublesome where there are no irrigation plants. The consensus of opinion seems to be that care must be exercised in the application of water on account of this disease.

One advocate of spraying for the irrigation of cucumbers claims that he has paid for his plant easily by the added yields from irrigation within the last few years. He considers the spray system valuable not only because of its ability to supply water in dry times, but also for the purpose of preventing injury to the young plants by the blowing sand, from which more or less trouble is experienced during the spring.

Opinions differ concerning the use of the spray system as a protection from frost, some claiming that a medium frost will do no harm if irrigation is begun immediately before daylight and continues for some time after the sun is up, while others believe that no harm will come to the plant if the frost is washed off early in the morning. Many irrigators claim they have tried the overhead spray as a frost protector with absolutely no benefit. Whatever the fact, it does not seem to be a general practice to depend on the irrigation plant for frost protection in spite of considerable evidence in its favor. There is no doubt that spraying is of little use, however, in time of extraordinary cold weather or when the thermometer registers below the safety point for a considerable length of time.

Experience with steam pumping plants in this district indicates that, while economical in operation, they have some serious drawbacks, chief of which is the inability to irrigate immediately on account of the necessity to get up steam. This might be a serious objection in times of sudden high winds, which might cause much damage before the irrigation plant could be put into operation. The same might be true to a less degree in times of sudden drop in temperature. Gasoline engines can be started at once when in good running order. It should be stated in favor of the steam engine, however, that it is kept in order easily, while as much can not always be said of the gasoline engine.

The time and number of waterings necessary are dependent on the rainfall, except when frost or blowing sand must be combated. In any case, the time of irrigation is entirely dependent upon the weather conditions. Dry weather in the spring causes great loss

some years, and the disastrous droughts of 1907-1910 were the direct cause of the installation of most of the plants. Some farmers have not used their systems for irrigation for two or three years, but most of the growers found water of great benefit in the spring of 1914. In case of a protracted drought water may be turned on nearly every day and run only a few hours, or a good wetting may be given at intervals of a week to 10 days. The quantity of water applied is not difficult to estimate, most of the plants delivering 40 to 50 gallons per minute per acre, which is equivalent to about 0.1 inch of rainfall per hour. Thus, if a man operates his plant 8 to 10 hours he probably will apply about an inch of water.

It is a peculiar circumstance that the irrigators in this section should have adopted overhead methods so readily when most of the soil conditions are well fitted for surface methods. Some farmers believe that watering by surface methods will increase blight, but there seems to be little proof of this. At present about 75 acres are watered by the surface or furrow methods, apparently with excellent results. The method of distributing the water is crude and much labor might be saved by better methods.

The question of methods will be taken up under a discussion of furrow irrigation. There is no doubt that it is worth much study, for if results can be obtained by irrigation plants of low cost it is quite certain that many farmers who now hesitate to pay an average of \$250 per acre for a plant would be willing to expend \$50 per acre.

The trucking section in Sumter County is considerably larger than that in Levy County. The largest acreage of irrigated lands is around the town of Bushnell, about 50 miles south of Williston. Some irrigation is practiced near Center Hill and Webster, each within 11 or 12 miles of Bushnell. This district comprises 250 to 300 acres of irrigated crop, nearly half being located around Bushnell. Practically all of this tract is irrigated by the overhead-pipe system, but a few acres are irrigated by other spray systems and a few by surface methods. The soil conditions are not favorable here for surface irrigation under the ordinary methods of applying water, because of the flat ground surface and the sandy character of the soil.

The water supply is from wells, which average about 125 feet in depth, the water rising to within 50 feet of the surface. Most of the irrigated farms are small, few being over 10 acres in extent, while many contain only about 3 acres. For this reason gasoline engines are in favor, few steam plants being in use.

Cucumbers are the principal irrigated crop, as in the Williston section. There is a large acreage of beans and tomatoes near Webster and Center Hill, but irrigation of these crops is not a common practice, the farmers believing that the increase in yield due to irrigation will not warrant the outlay for installation.

Many of the cucumber growers use an ingenious device for protection against frost. When indications point to coming frost the young plants are covered with wooden troughs 10 to 14 feet long, made of two 1 by 9 inch or 1 by 10 inch boards nailed together in the form of a V. These troughs are removed the next day, and when not in use, are allowed to lie between the rows. About 10,000 feet of lumber is required to protect an acre of vines, costing about \$120 to \$160. This is in addition to the average cost of \$250 for an irrigation plant, making an outlay of \$400 per acre, exclusive of the cost of the well, the land, and the growing of the crop. The common use of troughs for protection against frost on the same lands that are irrigated by overhead systems indicates the unwillingness of the growers to rely on spray irrigation for protection against loss from cold weather.

Another section of interest where overhead irrigation is practiced is in the vicinity of Bartow and Fort Meade in Polk County, 60 miles south of the Sumter County trucking section. About 450 acres are irrigated in this district. The chief crops are lettuce, cabbage, tomatoes, and eggplant, their importance being about in the order named. A good summer crop is sweet potatoes, which often yields heavily.

The average size of these irrigated farms is somewhat larger than that of the northern counties, being about 20 to 25 acres. One overhead-spray system covers an area of 100 acres. On this farm the water is supplied to the mains from bored wells by three gasoline engines and three 2-stage centrifugal pumps.

The owner irrigates about once a week during dry weather, giving the ground a good watering at each irrigation. He starts his engine late in the afternoon, running them 8 to 10 hours. This irrigation is equivalent to approximately 1 inch of rainfall. He says that he would not attempt truck farming without such a system, which he finds valuable at the time of setting the young plants and again at the time of maturing them. He uses small pasteboard boxes for covering young tomato plants when cold weather is expected. Some farmers, before an expected frost, cover the small plants with soil, uncovering them the next morning. Thus, in this section also, overhead systems are not generally used for protection against frost. The small cardboard boxes are cheaper than the troughs used at Bushnell, and are not such an impediment to cultivation when not in use.

A detailed description of other examples of overhead-pipe systems would be of doubtful value on account of their similarity to those already described. Probably 1,500 acres under other overhead-pipe systems are distributed over the State, several hundred being scattered through Manatee and Hillsboro Counties, mostly in small

patches used for the cultivation of winter garden crops. A considerable acreage so irrigated is located in Lake and Orange Counties, the largest part of it being near the towns, such as Orlando and Leesburg. There are about 200 acres under the overhead-pipe system along the Florida East Coast Railroad, principally near Miami. Some tobacco was irrigated by this system in Gadsden County in the north, a small area at Brookville in Hernando County, and at Dade City, in Pasco County.

Several other sprinkling systems are attracting considerable attention. The method of distribution for all of these is practically the same, however. It consists in placing nozzles upon upright pipes and distributing the water in a circular area, the nozzle being the center of the circle. If a field is to be watered, a number of nozzles are placed over the field so that when all are in operation the whole area will be watered simultaneously.

A large variety of nozzles are used for the distribution of water from these upright pipes. Most of these are patented and bear the names of the inventors. Probably the first to be put into operation were those which have no revolving parts. (Pl. IV, fig. 2, Nos. 4 and 5.)

Another nozzle has been in use for several years. (Pl. IV, fig. 2, No. 2.) There are several variations of this nozzle. The distribution is effected by a revolving part which whirls very rapidly and throws the water in all directions. The water falls in large drops.

Other nozzles recently have become well known. (Pl. IV, fig. 2, Nos. 1 and 3.) These also distribute the water by means of revolving parts, but on a different principle from that of the ones described. The water is distributed through hollow, adjustable arms of small brass tubing, revolving about a central axis. The action of the nozzles is adjustable. Both the nozzles are operated by the force of escaping water; in the former the water strikes against the revolving part, and in the latter the force comes from the recoil of the water in a bent tube. Most of the well-known lawn sprinklers having long revolving arms are operated on the latter principle. The irrigation nozzles differ from the lawn sprinklers in that wider distribution is attempted, the size of the nozzle being kept as small as possible. All the nozzles described are small and may be covered easily by the hand. (See Pl. IV, fig. 2.)

Some attempts have been made to adjust pipe lines bearing nozzles so that a long length of pipe can either be revolved about a vertical axis or carried on wheels from one end of the field to the other. Both of these methods have been operated successfully at Bushnell, but their use is too recent to prove their lasting qualities.

The largest acreage irrigated by means of the stationary or revolving nozzles is on the east coast around Miami. Several hundred acres here are so irrigated. These types are also installed on 200

to 300 acres in the western part of the State, the largest acreage being in Polk and Hillsboro Counties.

Spray irrigation has been found to be of considerable value as a protection against frost in the southern part of the State. Some farmers claim they have saved their entire crop from frost injury by their spray systems.

The installation of a complete irrigation system covering several acres by means of these nozzles does not differ greatly from that of the overhead-pipe system, the pumping outfit and main line being similar in both. The lateral lines of the overhead-pipe system must be elevated above the ground surface, as every nozzle is turned on at once. The laterals of the other systems usually are placed underground, while the nozzles are elevated by means of upright pipes connected to the underground lines. In the overhead-pipe system the lateral lines are placed perpendicular to the main, the size of the pipe increasing toward the main as the length of the lateral line is increased. The circular nozzles are placed close enough together so that water from one will overlap the space watered by its neighbor. The parallel laterals also must be placed close enough together for the irrigated spaces to meet. It is evident that this distance will vary with the radius of distribution of the nozzle. The nozzles of alternate laterals usually are placed opposite, so that the circular areas covered by all the nozzles will fit into each other.

It is not necessary to go into details of the design of pump and engine, as it will be seen that if the capacity of each nozzle is known the problem differs in no way from that of the overhead-pipe systems. The stationary-nozzle types usually require considerably more water than the other system, and this means larger pipe lines if the same amount of land is to be irrigated at one time. Each lateral is fitted with a cut-off, as in the case of the overhead-pipe system, so that any amount of land required may be watered simultaneously, provided the main and the pumping outfit are of proper size and capacity. The pressure required is about the same for all the overhead systems.

Advocates of the whirling-nozzle type claim that their systems are automatic and need no turning by hand. The advocates of overhead-pipe systems claim that this difficulty can be overcome easily by installing an automatic turning machine, and that the turning of the lines by hand is very simple and requires little time away from other work. The small aperture in the overhead-pipe nozzle may cause trouble by becoming clogged with small pieces of sand or fiber. This does not happen usually with some rotation nozzles, but may stop others. Good screens or filters will stop this trouble to a large extent. The smaller nozzle may be cleaned with a pin and the rotating nozzles

started again with little trouble. The manufacturers of both types have sought devices that would prevent the clogging of the nozzles, and improvements are being made constantly for both. The larger amounts of water applied per minute is one of the main advantages claimed by the advocates of the whirling-nozzle type, the opinion being that more water is needed for the east-coast soils than is commonly supplied by the overhead-pipe system. This is denied by users of the latter system, who claim they get good results, and in any case could get more water by placing the nozzles closer together and using larger lateral pipe. Probably the main difference in the system is that the overhead-pipe system must have posts placed in the field, which are more or less of a nuisance, some trouble to keep up, and are often unsightly, especially in Florida, where it is common practice to use posts that are cut on the farm. The other systems present a much neater appearance, which is especially pleasing in the case of the irrigation of a flower garden or a private winter estate. For this reason, many of the large estates near Miami are watered by these systems on this account. The matter of appearance, however, is of little importance to most irrigators.

There is a great difference in cost, which often is of primary importance. Some of the systems covered by the old stationary nozzles, used for watering gardens, have cost more than \$500 per acre. This high cost is due to the necessity of placing lateral lines close together. From \$200 to \$500 per acre probably would be an average cost for a complete system for a 5 to 10 acre truck patch. The average rotating-nozzle type will average \$200 to \$350 per acre installed, and the overhead-pipe system \$175 to \$275. Some of the stationary-nozzle systems are not liable to get out of order, and will accommodate almost any kind of dirty water. Other rotating-nozzle and overhead-pipe systems do not operate well unless the water is clear.

The distribution of water is better effected by the overhead-pipe system than by any other, being practically perfect if the lines are turned at the proper time. Distribution by the whirling nozzles depends considerably on the wind. If there is a good breeze the distribution will be even, but if the air is still there is unevenness in watering on account of the untouched spaces between adjacent circular watered spaces. The smaller nozzles of the overhead-pipe type apply water in fine drops, which is of considerable benefit in some localities, but it is doubtful if this makes any appreciable difference in the sandy soils of Florida.

The advantages of the overhead-spray systems are many, the chief ones being the ease of irrigation and the absolute lack of manual labor attached. The rapidity of applying the water and the evenness of distribution are of great importance, especially at the time of set-

ting young plants. This advantage is of more consequence in Florida than in the more northern States on account of the exceedingly sandy nature of most of the surface soils. The rapidity with which these soils dry out makes frequent irrigation necessary in dry weather, and this can be done easily with the overhead system without wasting water below the root area. It is necessary to fertilize most of the truck crops in Florida very often in order to assure rapid growth, but fertilizer is of little effect if the surface soil is dry. The overhead system dissolves this plant food and makes it effective in a short time. As has been pointed out already its value as a protection against frost has not been thoroughly demonstrated in all parts of the State but there are many overhead systems which are used successfully for frost protection, especially in the southern section. The use of spray systems for washing off dust and certain lice from plants is advocated by some, and the application of certain insecticides through the pipe lines has been suggested, but so far as the writer is aware this has not been attempted in Florida.

The disadvantage of this system lies primarily in its high cost of construction. An outlay of \$200 to \$500 per acre is heavy and means that the application of the water must bring in additional income above the cost of maintenance and yearly interest on the first outlay. The cost of operation is very light in most cases, averaging not more than \$3 to \$5 per acre per year for fuel. Labor cost of irrigation may be neglected for the small plant, and most of them are small. Depreciation of engine and pipes may be estimated at 7 to 10 per cent, and if repairs are considered, the higher figure should be taken. Interest charges are high in Florida, and should not be put under 7 per cent. Thus, if a plant cost \$300 per acre, including entire system and well, the annual interest charges would be \$21, depreciation about \$30, and operating expenses, not including labor, about \$5, or a total of \$56 per acre. Thus it is seen that in order to come out even on his investment the farmer must make \$56 per acre more on his irrigated crop than he would if the crop were unirrigated; and he must do this every year, as it will cost nearly as much to keep the plant during a rainy season as during a dry one, since only operating expenses are low in a rainy season.

It was shown under the discussion of the Sanford subirrigation systems that the cost of growing some of the truck crops is very heavy, even though no irrigation is considered. This is true throughout the State. Sometimes large profits are made without irrigation, but, again, heavy losses are sustained in times of drought. This possibility of loss is what should determine the permissible cost of an irrigation plant, and most of the owners of overhead irrigation plants claim that the plants pay; some say they do not, while a large number admit that they do not know. It is easy to see,

however, that to erect an overhead system for the irrigation of most of the field crops, where a yearly profit of \$50 per acre is supposed to be good, would be to lose money from the beginning. In any case, the farmer should look into his conditions carefully before irrigating, and be very sure that he can not get results from cheaper methods. In many cases he will find that he can not, but there are many cases where he can, and it should be his first duty to investigate.

THE FURROW METHOD AND OTHER SYSTEMS USED FOR IRRIGATING TRUCK.

The two systems of subirrigation already described and the several systems of overhead spray include 80 to 90 per cent of the area of irrigated truck in the State. The remainder is covered by various methods coming under the common designation of surface irrigation.

The largest area of garden crops irrigated by surface methods is in Manatee County, where it is estimated that 1,000 to 1,500 acres are irrigated in this way. A small acreage of strawberries in Hillsboro County is irrigated by surface methods. Other patches are scattered through the State, probably totaling not more than 500 acres.

The methods employed are very simple in most cases, many of the farmers running water in open ditches and letting it flow down between the rows, regulating the flow by means of a shovelful of soil at the head of the furrow. Some farmers use lengths of hose to aid the flow in the furrows, while others use light-weight pipe to convey water over the field. The objections to these systems are that they are wasteful of water, and that there is a considerable amount of labor attached to their operation. The possibilities in irrigation by the furrow method are worthy of careful consideration and doubtless it will become much more popular when better methods of distribution are employed.

IRRIGATION OF CITRUS GROVES.

The need of moisture for citrus trees was taken up to some extent under the discussion of soil tests. It was shown that the soil is commonly very dry for long periods, producing a harmful effect on the trees.

In order to determine the benefits accruing from the irrigation of citrus groves, a portable pumping plant was procured which could be taken from one grove to another. Such a plant will irrigate one or two rows in an unirrigated grove; and the difference in yield and quality of the fruit is observed later in the season. In this way exact data may be obtained which will give the farmer some foundation on which to estimate the allowable cost of applying water to the tree. No definite data have yet been obtained.

A great many orange and grapefruit growers claim that the benefits from irrigation are not worth the expense of installing and maintain-

ing a plant. On the other hand, many farmers have paid large sums for irrigation plants and seem to be well satisfied with the investment. There is, of course, room for much study of methods of applying water, amounts of water required, and proper times of application. These questions can be partly solved by the aid of the portable plant mentioned above. The question of methods of construction for both pumping machinery and distributing lines also is important, and will be taken up in detail elsewhere.

The annual growth of orange and grapefruit trees may be divided into four periods. The first period is in the spring when the blossoms appear and the young fruit forms; the second in the rainy summer months when the fruit takes on size; the third in the fall and early winter when the fruit is maturing and harvest begins; and the fourth in the dormant season, usually through the months of December and January. The winter and spring seasons also are the harvesting seasons in most sections of the State. The first period is the most critical from an irrigation standpoint, as dry weather may cause the young fruit to drop. The rains usually are abundant in the summer months and irrigation is not needed. The second dry period, which usually occurs in the fall, may do serious harm by preventing the fruit from attaining full size and color, as well as causing it to drop. This dry season occurs throughout the entire winter and spring months in some cases, as may be seen from the rainfall charts. Some orchardists believe that irrigation never should be practiced in the dormant season for fear of starting new growth too early, which may be killed by frost. Rainfall, however, is quite common through December and January and seems to do no harm unless accompanied by warm weather, which will start the young growth early even though the ground be dry. Generally speaking, it probably is well to wait until signs of new growth appear in the spring before beginning irrigation in frost areas, unless trees are in a wilted condition due to lack of moisture.

The amounts of water needed depend upon the condition of the soil at the time of irrigation, and will be discussed in connection with soil tests during irrigation.

HOSE IRRIGATION FOR CITRUS GROVES.

By far the most common practice in irrigating citrus groves is by the hose method, which may amount to a simple spraying by hand in connection with sprinkling systems, or in combination with furrow methods. There are two large groves where this form of irrigation is used in Manatee County, within a few miles of the town of Palmetto. One covers 240 acres and the other 370.

The latter property is located about 2 miles below Palmetto, which is on the Manatee River about 25 miles south of Tampa. The topog-

raphy of the grove is flat to gently rolling, the highest elevation being not more than 10 or 12 feet above sea level. The surface soil is light and sandy in some parts and a good quality of low hammock in others, the latter type being very light and porous. The soil is shallow over all the grove, there being a substratum of rock or hardpan under nearly the entire grove. The depth of this substratum varies, averaging about 20 inches beneath the surface. On account of the low character of the ground the trees are grown on ridges to prevent flooding out during periods of excessive rains.

Notwithstanding the low-lying topography and the frequent need of drainage due to excessive rainfall, there often is a very serious need for irrigation. This is caused mainly by the long periods of drought, but is partly due, also, to the extreme shallowness of the soil, since the moisture absorbed by the trees can not be replenished from below on account of the layer of impervious rock.

The water supply for the irrigation of this grove is obtained from two 6-inch artesian wells. Each well is about 600 feet in depth, and when allowed to flow freely will supply about 400 gallons per minute, exerting a pressure of 7 pounds per square inch when capped. Several patches of garden vegetables scattered through the grove are watered by the wells at their natural pressure. When it is necessary to irrigate the grove this pressure is supplemented by a 2-stage horizontal pump having a capacity of 700 gallons per minute and operated by a 50-horsepower gasoline engine.

The distribution system consists of about 33 miles of iron pipe, varying from 1 inch to 6 inches. A 6-inch main delivers the water to laterals varying in size from 4 inches at the main to 1½ inches at the ends. The laterals, which run parallel to each other, are placed along every fourth row of trees, the tree rows being 25 feet apart. One-inch pipe uprights are connected to the laterals at intervals of 100 feet. The hydrants are placed under trees and stand about 2 feet above the ground on the 1-inch pipe uprights.

In connection with this system there are 50 pieces of 1-inch garden hose, each about 50 feet long, and 50 movable sprinklers, each sprinkler being attached to about 6 feet of 1-inch pipe. This pipe is sharpened at one end and has the nozzle at the other, with a hose connection about 1 foot from the bottom. When in use the sharpened end of the pipe is pushed into the ground and the apparatus is connected by hose to a convenient hydrant. The pipe thus stands upright, delivering a spray of water through the nozzle, and, in this position, may be left temporarily while other pipes are being set up.

Fifty of these nozzles are in operation when irrigation is in full force. Each nozzle is placed in the center of the square formed by four trees, the spray watering one side of each tree when in a single

position. The sprays when running under a pressure of about 40 pounds per square inch will each deliver 12 to 15 gallons per minute. Each nozzle is allowed to remain in one position about 20 minutes, which means an operation of about 80 minutes for each tree, as four set-ups of one nozzle usually are required to complete the irrigation of one tree. This amounts to about 1 inch of water over the grove. The operation of this system requires the work of six men—five in the field to move the nozzles and one at the engine.

The chief objection to this system is that it takes too long to irrigate the entire grove. When the system was completed for one-half of the grove three weeks was required to irrigate that portion of it. At this rate it would take about six weeks to irrigate the whole grove, which is much too slow for any part of Florida, and especially for the shallow soils of this section. The time might be shortened by night irrigation, but night labor is very hard to obtain. More wells and pumping units would permit faster work, and these will have to be installed before the plant can be regarded as entirely satisfactory, since it is obviously impossible to irrigate successfully 370 acres with only 700 gallons of water per minute.

The cost of the plant, exclusive of the wells, is about \$35,000, or about \$100 per acre. This is much lower than could be expected for a plant serving a small acreage, and would be somewhat higher, of course, if the grove could be irrigated in less time.

This type of system, as used in a large grapefruit grove near Palmetto, differs only in the spacing of the hydrants, which are 90 feet apart instead of 100 feet, and there are many systems similar to this all over the citrus section of the State, although the average irrigated grove is much smaller, probably amounting to from 10 to 20 acres. A wide variation exists also as to the size of laterals and the spacing of the hydrants. Many of the groves have a hydrant spacing of 150 feet, a 1½ or 2 inch hydrant being used, and about 75 to 100 feet of hose. The smaller groves, as a rule, are not equipped with the movable nozzles, some irrigators simply letting the water run at the foot of the tree or directing the spraying of the trees by hand while moving from place to place through the grove.

The great trouble with many of the systems described above is that the owners try to economize on size of piping and pumping outfits. Some irrigators apply insufficient quantities of water. It is very doubtful if the application of small quantities is of any material advantage, as the soil often is merely packed, which spoils the dust mulch and thus aids evaporation.

ORCHARD IRRIGATION BY AUTOMATIC-SPRINKLING SYSTEMS.

The automatic-sprinkling system also is used in orchard irrigation, both the overhead-pipe and the rotary-nozzle types being

adapted to this purpose. Although the total acreage so irrigated is not large the system has attracted considerable attention. The entire area irrigated by overhead-pipe system does not exceed 10 or 15 acres. The same method is employed as for the irrigation of truck patches, except that it is necessary to keep the pipe lines above the foliage of the trees. This is not difficult in the case of small trees but trouble is experienced when the trees are large.

By far the greater area of automatic-sprinkled groves is covered by some rotating-nozzle system. This differs from the overhead-pipe system only in minor detail. The nozzles should be kept above the trees in order that the foliage may not interfere with the discharge or the distribution of the spray. A large grove irrigated by this system is at Lucerne Park, and includes 60 acres. Water is taken from a near-by lake and forced through the pipe lines by means of a 2-stage centrifugal pump operated by a 35-horsepower gasoline engine. The main consists of a 6-inch steel pipe, with 2-inch to $\frac{3}{4}$ -inch laterals running at right angles to the main every second row. The nozzles are set on uprights near a tree, standing 2 or 3 feet above its top branches. They are spaced 50 feet apart and so arranged as to form a diamond-shaped figure. When the plant was installed the trees were young, standing above the ground only a few feet, but as they attained greater height it was found necessary to add a length of pipe to the uprights. The cost of the system has been high, that for the first 10 acres totaling over \$500 per acre, although it was estimated that the entire 60 acres could be put in for about \$250 per acre.

When this type of system is in good order it is difficult to find an easier way to irrigate a grove. No labor is attached to the process other than starting the engine and manipulating a few valves. In the grove at Lucerne Park the system will water 5 acres at one time, applying an inch of water in about 4 hours. Thus, if the plant were run continuously for 48 hours, the entire 60 acres could be covered to a depth of 1 inch, the water being diverted from one 5-acre unit to another once every 4 hours. Other advantages also are claimed, one being that it will wash off the red spider, a mite which does considerable harm to the tree in dry weather. A good washing will drive away this pest, but this may be accomplished cheaply by the use of any of several insecticides which are applied easily with any good spraying machine. Some believe that this system will prove a good protector against frost, although this claim is disputed. In any event it would be hard to keep a 60-acre grove constantly watered with a 5-acre unit. There are certain designs of apparatus which will turn water automatically very rapidly from one unit to another, but these require a peculiar method of laying out the lines and are not in actual practice so far as the writer is informed.

Nevertheless, there are disadvantages to this system, the most serious perhaps being the first cost, which is too high for the average grower to consider. Inasmuch as the citrus trees in Florida grow very tall after reaching the age of about 20 years, another objection is the trouble experienced from nozzles when it becomes necessary to elevate them above the reach of the hand. This is a considerable drawback since the nozzles are likely to need attention as they become worn or clogged. An irrigation system should be put in with the idea of having permanent effectiveness, for it seems that the older a tree the more water it needs.

IRRIGATION OF GROVES BY SURFACE METHODS.

To one who has seen the systems employed for the irrigation of orange groves in southern California, it is somewhat surprising that the California methods are not in more general use in Florida, as many of the growers had visited the western systems before they installed these entirely different systems in their own groves. The furrow systems of the West are not more widely used in Florida, however, because of the difference in soil conditions, the conclusion having been that the loose and sandy soils of Florida would not permit the running of water for long distances upon the surface of the ground. Yet some prominent growers in Florida have irrigated their groves by this method with reported success. Probably the best-known grove where this method has succeeded in spite of sandy soil is a grove on Lake Butler, about 10 miles west of Orlando. The manager of the grove reported to the Florida Horticultural Society in 1907 that he had used the furrow system with success during the protracted drought of that season, running water down furrows 500 to 600 feet, and that he was using successfully a main of 10-inch terra-cotta pipe as well as several hundred feet of light portable galvanized sheet-iron pipe. The latter may be carried easily from place to place and may be made to carry water where the grades do not permit running it in furrows.

Another example of furrow irrigation in Florida is a grove at Winter Haven. The plant consists of a steam duplex pump, capacity about 200 gallons per minute, operated by a 30-horsepower engine. The main pipe line runs from the lake to the center of the 50-acre grove. Outlets consisting of 5 by 3 inch iron crosses are provided on the main, 125 feet apart. The 3-inch outlets face at right angles to the main, each being provided with a 3-inch iron gate valve. In connection with the above there is enough 3-inch iron pipe to reach from the main to the outside of the grove. This pipe is carried from place to place as it is needed.

Before the water is turned on the land several furrows are plowed in each space between the tree rows parallel to the main, and

others are plowed at right angles to these. When irrigation is begun, the men start at the far end of the main line, connecting a length of the 3-inch pipe to one of the valves and lightly screwing enough 3-inch pipe together to reach the edge of the grove. The water is then turned on in furrows prepared previously. When it has run down a furrow about 125 feet it is stopped and made to flood the trees from the lower end up toward the pipe. When the trees have been well watered other lengths are unscrewed from the 3-inch pipe and the operation is repeated. When the top end of the grove is watered the same operation is repeated from the next hydrant on the main, which is situated 125 feet below.

This method of irrigation has been satisfactory and seems to please the owner. Light portable pipe made of about 24-gauge galvanized iron 6 inches in diameter, instead of the 3-inch screw pipe, would have been more satisfactory, the iron screw pipe being heavy to shift. The cost of the plant is very low, but can not be stated exactly, as the material was purchased secondhand; but such a system of all new piping would be very cheap, compared with the systems in general use in Florida.

A number of the systems in operation in Florida may be termed partial furrow systems. Some of these have distributing systems similar to the hose systems already described, using hose to run the water down short furrows. Most of these, however, are supplied with heads of water too small to bring good results.

In some instances the water is distributed over the grove entirely by means of portable pipe, there being no permanent mains whatever. A notable example of this is in a grove near St. Petersburg, Fla. The plant waters 21 acres of full-grown orange and grapefruit trees, some of which are over 30 years old and of enormous size. The soil is exceedingly loose and sandy, probably as porous as any of the grove lands in the State. The water supply is obtained from a deep bored well 8 inches in diameter and located in the highest part of the orchard. The water rises in the well to within about 50 feet of the surface. An impeller pump is used to lift the water from the well to the surface. This pump has a capacity of about 700 gallons per minute and is operated by a 50-horsepower kerosene engine. The distributing system consists of 1,000 feet of 9-inch portable pipe of 24-gauge galvanized sheet iron in 10-foot lengths, constructed with taper ends so that one joint will fit into another like lengths of stovepipe. No other pipe of any kind is connected with the distributing system.

The operation of this system is very simple, requiring the labor of only one man. The furrows are run down grade, three being made at one time by a contrivance devised by the owner of the grove. Other furrows run at right angles to these. When water is turned

on, the portable pipe is connected by pushing the joints together, and through it the water is transported to any desired part of the grove. The furrows carry the water some distance, which reduces somewhat the labor necessary in transferring the lengths of pipe. The work is hard and requires some experience and judgment, but the results are highly satisfactory and the plant is cheap and durable. The pipe costs 20 cents per foot, or \$200 for the entire distributing system, which is less than \$10 per acre. The cost of the well, pump, and engine was very high, on account of the difficulty of drawing water from a bored well where the water level stands 50 feet below the surface of the ground. Construction of a pump pit was difficult, as the sandy soil extends to great depths. If this place bordered on a lake, as do many of the Florida groves, the total cost per acre would have been light.

IRRIGATION OF GROVES FROM FLOWING WELLS BY THE SURFACE METHOD.

The method of irrigation from flowing wells, as practiced extensively in Lee County around Fort Myers, is cheap and efficient. The groves irrigated by the free flow of water from artesian wells are necessarily on the lower lands, as flowing wells are not obtained on the higher elevations in the State, and, as a rule, can not be expected above the 50 to 60 foot contour. (The highest elevation in Florida is about 275 feet above sea level.) The ground surface in the Fort Myers flowing-well area is mostly level, nearly all the groves requiring drainage during the rainy season. The trees usually are grown on ridges or embankments of earth in order to keep them above standing water in times of heavy rainfall. The depressions between the rows also act as drainage ditches to carry off any excess water.

The average depth of wells here is about 500 feet. Some have a strong flow and exert a pressure as high as 20 pounds at the well when capped. The cost of wells depends on the size and depth and varies from \$500 to \$1,000. The average well in most groves will water 20 to 40 acres. Some of the larger groves have a number of wells in convenient locations.

Between 2,000 and 3,000 acres are irrigated by this method in Lee County. Some of the larger groves contain 100 to 500 acres, the average size of the irrigated grove being about 50 acres, most of which is in grapefruit.

Distribution of water in this section requires no particular refinement of methods, as the supply is abundant and there is no operating cost after the well is dug. For the distribution of water most of the growers use open ditches, which require no particular attention. Others run water in several furrows in each space between the tree rows, sometimes using rough wooden control gates.

These lands need water badly when the rainfall is light, as the ground dries out rapidly. Conditions here are similar to those in the Manatee section. It will be seen from the Fort Myers rainfall chart (fig. 3) that long droughts are very common, probably as much so as in any part of the State.

SUMMARY OF IRRIGATION PLANTS IN USE.

The above descriptions include all types of irrigation plants for trucking and citrus culture which are of any importance. It will be noted that all the plants are owned and operated by individuals, the irrigator owning his own water system and using it as he sees fit. He is not confronted with the water-right problems which vex the western irrigator, nor does he have to wait his turn for the water or pay irrigation district assessments. On the other hand, he has had to depend for information on men who were not experienced in irrigation methods, which often has meant poorly designed and costly plants, while his western neighbor has the advantage of the experience of previous generations of irrigators. The irrigation plants in Florida are scattered over a large territory, where the experience of one district may be of little use in another.

It will be noticed, however, that where there are uniform conditions of soil, water supply, and cropping, similar methods have been followed. This is true especially of the sections where flowing wells have been obtained. It is interesting to note that in the Sanford and Hastings trucking districts and in the Fort Myers citrus district irrigation is general, probably 90 per cent of the cultivated acreage being under irrigation. The average price of installation is low, probably less than \$10 per acre for the open-ditch systems of Hastings, \$20 for the Fort Myers systems, and about \$125 per acre for the systems used in the Sanford district. The need for irrigation is not to be denied and should be heeded if the water can be applied without too great expense.

Leaving these areas for less favored ones where water can not be supplied at such reasonable cost, entirely different conditions will be found. Many designs of plants are in use, most of them very expensive. This is due not entirely to the lack of flowing wells, but to the fact that soil conditions will not permit the adoption of the open-ditch or subirrigation methods, and the expense attached to pumping water would not allow such wasteful methods of applying water even if the soil conditions were favorable. Instead of the cost of plants ranging from \$10 to \$125 per acre it varies from \$100 to \$500 per acre, with very few near the lower figure. Large expenditures for the irrigation of truck crops doubtless are justified in many cases, but there is some question whether this is true in the case of the groves.

It is possible that the irrigation of the Everglades will become a problem that can best be handled by cooperative methods. At present too much drainage work remains to be completed to permit the formation of any decided opinion as to the best methods to be followed. The 280 miles of drainage canals now open represent only part of the main ditches which must be constructed. Many miles of lateral farm ditches for drainage also must be constructed before the entire area can be considered as offering any possibilities as an irrigated section.

At present the region offers no problem that has not been discussed above. There are a few acres of overhead-spray systems along some of the main canals and some land has been irrigated successfully by the furrow system, water being pumped from the drainage canals. It is quite certain that pumps will be the main source of irrigation for some time. The future alone will determine the feasibility of raising the water surface by structures placed in the drainage canals, thus reversing the purpose of the farm laterals so as to use them to supply water to the farm instead of draining off the water. The Everglades are not drained, as a whole, at present, although there are a number of individual drainage projects within the main drainage system which make possible the cultivation of limited areas.

What appears to be most needed to encourage the construction and operation of irrigation plants in Florida is a knowledge of cheaper installation for the higher and sandier groves, with cheap and efficient methods of distribution. Such methods are needed in many of the truck gardens and in many of the groves that lie on the lower elevations.

EXPERIMENTS TO DETERMINE METHODS FOR ECONOMICAL IRRIGATION.

The Office of Public Roads and Rural Engineering experimented with construction for irrigation by furrow or surface methods, and to determine the distribution of water in the soil when such methods are used. The results derived from these tests have been quite uniform and point toward greatly improved irrigation systems for the future.

SOIL-MOISTURE TESTS MADE IN CONNECTION WITH IRRIGATION.

The tests in soil-moisture content were made to determine the best heads of water to use for furrow irrigation and the length of time that should be allowed for irrigation. With these points determined, the best methods for applying water could be found. The tests were made at several points near Orlando, some being in connection with the use of the portable plant mentioned on page 38 and others with larger heads from large-capacity pumping plants. Experiments were made with several types of soil, but as the closer types offer no par-

ticularly difficult problems only the results of experiments made in the sandier soils will be given.

Figure 7 shows graphically the path of the moisture in the soil. The tests were made in a grove in the sandy soils of Maitland, in the spring of 1914 when the soil was very dry. The numbers in the vertical column show the percentages of soil moisture, while the numbers at the bottom of the chart show depth in feet. For instance, the top

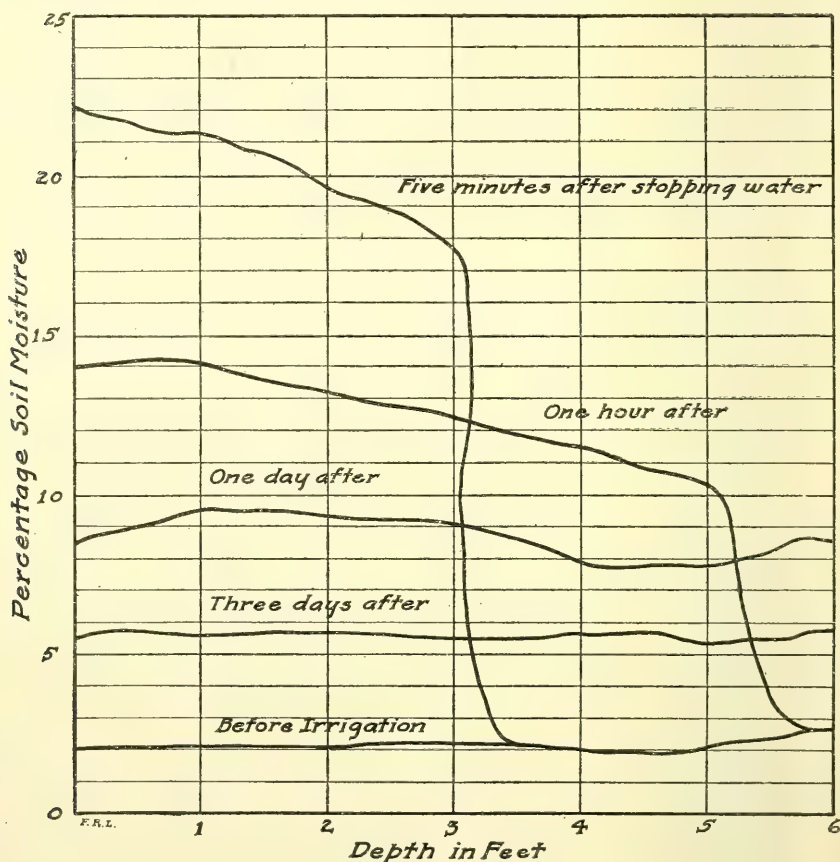


FIG. 7.—Curves showing percentages of soil moisture after running water at the rate of 70 gallons per minute in open furrows at Maitland, Fla.

curve represents the percentage of moisture 5 minutes after water had been turned off. It will be seen that there is a little over 22 per cent of moisture at the surface, about 21.3 per cent at the first foot, 19.5 per cent at the second foot, and 17.8 per cent at the third foot. The curve then drops nearly vertically and reads only 2.1 per cent at about 3.5 feet in depth, the moisture for the fourth, fifth, and sixth feet being the same as before the water was put on. Observation of the second curve taken one hour after this shows that the moisture content for the first 3 feet in depth has lowered but that the moisture

has extended to the fifth foot in depth. The other curves show the soil moisture one day and three days after, as well the the rapid disappearance of the irrigation water.

A great many interesting points are brought out by this chart, one of the most important from the irrigator's standpoint being the rapid

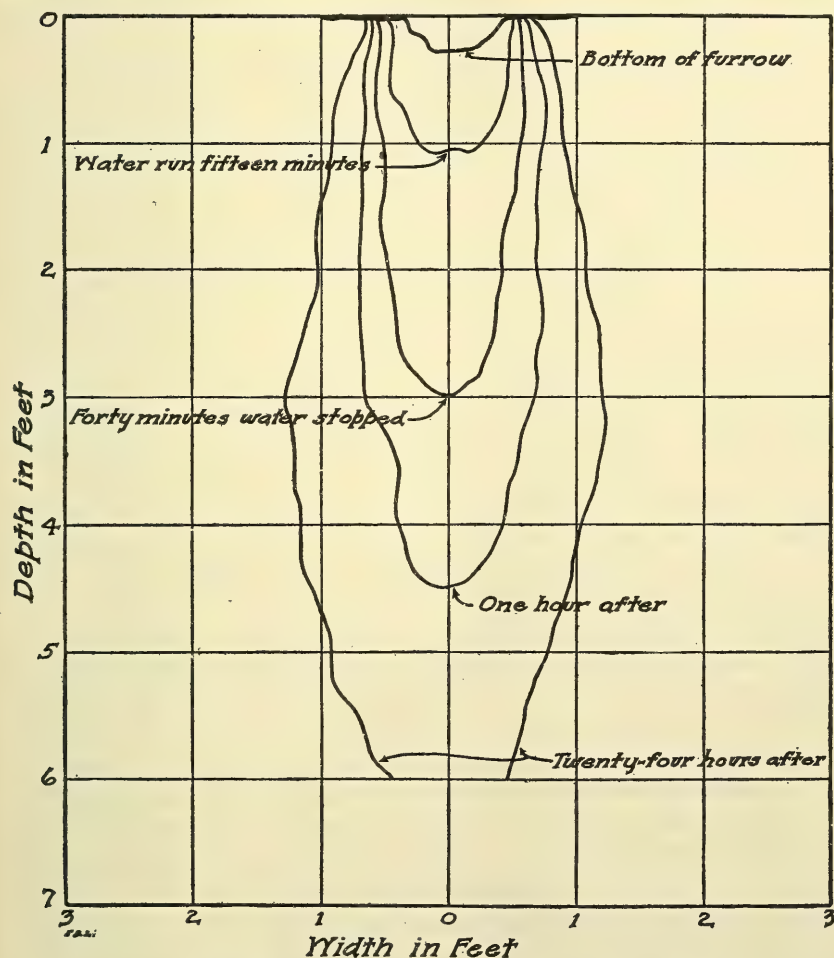


FIG. 8.—Cross section of water distribution shown in figure 7.

downward trend of the water when applied by flood or surface method. It will be noted that practically no water was lost by percolation or seepage below the sixth foot until more than an hour after the water had been turned off; after that time there was some loss. Water was run down a broad furrow at the rate of about 75 gallons per minute for 30 minutes.

Figure 8 shows a cross section of the same water distribution. In this case water was run 40 minutes over similar soil and with the

same head as that shown in figure 7. This chart does not show percentages of moisture, but does show the path of the moisture at different periods of time. The percentage of moisture can be estimated very closely from the other chart. This chart also shows that water will disappear rapidly below the sixth foot if run too long. The lateral distribution is very slight, hardly a foot on either side from

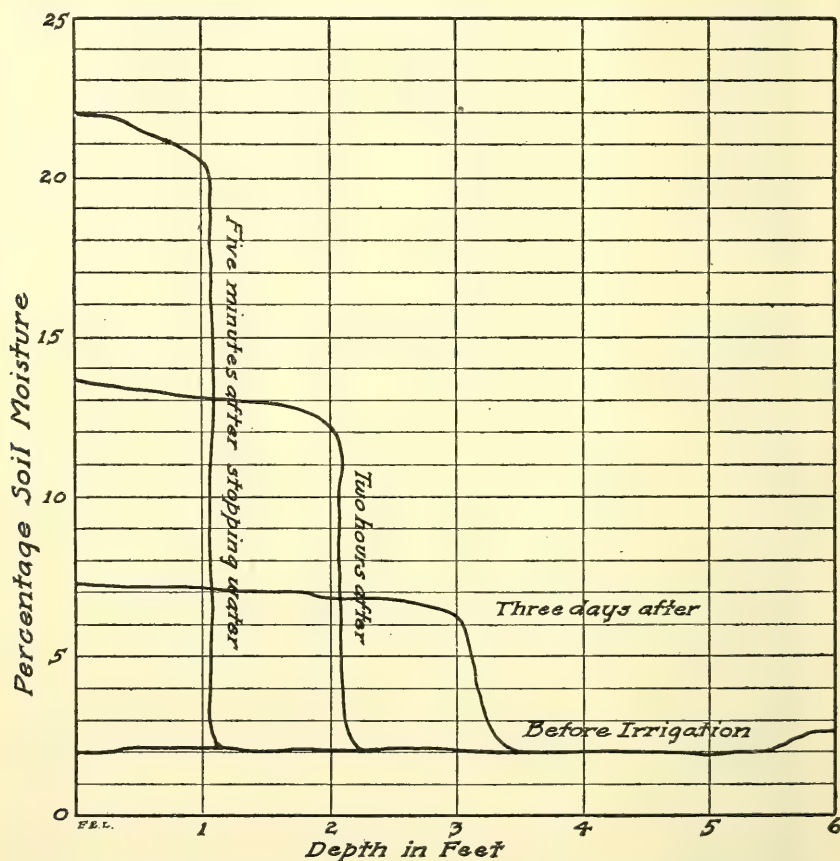


FIG. 9.—Curves showing percentages of moisture in the soil at different depths after running water at the rate of 10 gallons per minute at Maitland, Fla.

the edge of the furrow. The furrows are about a foot wide, which means that a 3-foot strip is watered from each furrow. Seventy gallons of water per minute was run down this furrow.

Figure 9 shows the same effect when water is run only 15 minutes. It will be seen that there is no waste of water below the third foot. A cross section corresponding to this curve would present an appearance similar to the one shown in chart 8, but would not extend beyond the third foot.

Figures 7 and 9 both show that before irrigation the soil was very dry all the way down, the moisture content averaging a little more than 2 per cent. In this condition this soil appears perfectly dry and could be used in an hourglass. When the moisture content reads 4 to 5 per cent the soil will hold together well when compressed in the hand, and when it contains about 10 per cent the soil is moist enough to pat to a smooth, shiny surface. At about 15 to 20 per cent water can be squeezed out. The above description will give a good idea of the state of the soil when any point of the curve is read.

Another point brought out by these tests and shown in the charts, is the distance the water will run down furrows. Tests made with different heads of water show that this distance is dependent on the head of water, provided there is some down grade to the furrows. For instance, if small heads of water were used it was found impossible to run water more than 100 feet in the grove at Maitland. Heads of 25 gallons per minute, considered large for California furrows, were useless in the sandy soils. Running the water for long periods did no appreciable good, as the water disappeared downward faster than it could be supplied; but when the heads were increased it was found that the length of furrow could be increased and that a head of about 120 gallons per minute would run a total distance of 650 feet.

The loose, sandy soils are peculiarly adapted for holding water on the surface for a considerable time when they are very dry. It is then possible to run good heads of water 600 to 700 feet. This could not be accomplished if the topsoil were moist, but as the soils usually are dry when irrigated the other condition need not be considered. The soils of many of the groves near Orlando and some near Tampa and Manatee were found to be much less porous than those of the grove at Maitland. In several of these cases small heads of water could be run long distances. Experiments in a grove at Orlando showed that heads of 25 gallons per minute were adequate for ideal furrow-irrigation methods.

It would appear from the above that if a grove is located on very sandy soils and it is desired to irrigate by furrow methods, the main concern should be to design the plant so as to supply these heads. This subject will be discussed in connection with actual construction of plants which have fulfilled such requirements.

EXPERIMENTS WITH LOW-PRESSURE PIPE SYSTEMS.

The term "low-pressure" pipe is used in this case to designate pipe that will not stand high internal pressure. Ordinary cement pipe and terra-cotta sewer pipe come under this head. Steel, cast-iron, and wrought-iron pipe will withstand high pressure without bursting.

The first experiments by the writer in Florida were made in a grove near Orlando, in 1909. The owner of the grove had set up a 25-horsepower engine and a pump which did not work satisfactorily. He was advised to install a single-stage centrifugal pump, capable of delivering about 700 gallons per minute to the highest part of the grove, about 35 feet above the surface of the lake from which the water supply was obtained. Two 5-inch wrought-steel mains carried the water to the top of the grove, a distance of about 500 feet.

The question now was how to distribute this water to the best advantage from the end of the main without expending large sums of money on iron or steel piping systems. Upon making a survey of the 40-acre grove it was found that all of it could be covered by a pipe system requiring heads of water not larger than 10 to 15 feet after the water had been pumped through iron pipe to a high point in the grove. Concrete pipe has been found satisfactory in some parts of Florida, but the poor grade of sand which had to be used discouraged its general use there. The sand was procured from Lake Weir and is considered good for ordinary concrete work, such as building blocks; but a sharp, clean sand should be selected for good concrete pipe, such as is used for irrigation purposes in the West. The principal objection to this pipe was the difficulty, with the labor available, of concreting the separate joints together so as to make them watertight. This could be accomplished in several ways, but would require special apparatus and considerable care.

Terra-cotta sewer pipe was found to answer every requirement, although care was necessary in laying it. (Pl. V, fig. 1.) The remainder of the distributing system was, therefore, finished with the terra-cotta pipe, which has given the best of satisfaction during the last six years, and judging from its use throughout both East and West it should continue satisfactory for an indefinite period.

The outlets from the terra-cotta distributing system were made by connecting special irrigation valves to short upright pieces of 6-inch terra-cotta pipe, which were connected to the main pipe by the ordinary terra-cotta T. Six, eight, and ten-inch pipes were used. These were laid in trenches on the highest ridges throughout the grove. The pipe was cemented together so as to make water-tight joints, and was then covered with earth, the top of the pipe then being at least 12 inches beneath the surface.

Probably the most important item in the construction in this grove was the arrangement to prevent excessive pressure in the terra-cotta pipe. If the iron main from the pump were connected directly to the terra-cotta pipe it is probable that the pipe would burst from water hammer, or sudden starting or stopping of the water. To prevent any possibility of this a relief standpipe was constructed at the



FIG. 1.—LAYING VITRIFIED TERRA-COTTA PIPE IN CITRUS GROVE, ORLANDO, FLA.



FIG. 2.—FURROW IRRIGATION IN CITRUS GROVE, ORLANDO, FLA.



FIG. 1.—RELIEF STANDPIPE AT CONNECTION OF IRON DISCHARGE PIPE AND TERRA-COTTA DISTRIBUTING LINES, IN ORANGE GROVE, PALATKA, FLA.



FIG. 2.—SIX-INCH CAST-IRON IRRIGATION VALVE AND HOSE CONNECTION TO SLIP-JOINT PIPE FOR IRRIGATING ORANGE GROVE, PALATKA, FLA.

point where the iron main from the pump connected with the low-pressure distributing system. This relief stand consisted of a concrete box about 4 feet square and 12 feet high, open at the top. The iron mains entered near the bottom on one side and two terra-cotta pipe lines led out near the bottom of the stand. Each of the terra-cotta outlets was fitted with a sliding gate which could be opened or closed by means of a long handle from the top of the relief stand. The top of this relief stand, or standpipe, was 3 feet above the highest elevation of the grove. If every valve in the terra-cotta lines was closed the water would rise and overflow the standpipe without exerting excessive pressure on the distribution system.

Water was distributed over the grove by diverting it into furrows, three or four furrows being placed between each two tree rows (Pl. V, fig. 2). In order to facilitate the distribution, outlet valves were placed in every tree row, and seven or eight of these were sometimes left open at the same time, thus permitting 24 to 28 furrows to be supplied with water simultaneously. Water ran 400 to 500 feet in the furrows, and only one man was needed to operate the system. The furrows were made with an ordinary sweep shovel plow.

The outlet valves installed first were similar to those used extensively in southern California for orchard irrigation, and allowed the water to escape in four or five small streams from a central stand. Trouble was experienced with these in keeping the water divided into the furrows in sandy soils; hence the above-mentioned local type, which did the work much better, was devised.

The improved valve, as designed for the experiment, is being used now for special Florida conditions on low-pressure pipe systems. It is made of cast iron and brass and is expected to stand low heads only. Its operation is very much like that of the ordinary hydrant and it may be regulated to discharge various amounts of water. The ordinary 6-inch size is made with either one or two outlets. The two-opening valve is used when furrow irrigation is practiced, while the one-opening valve is used in connection with portable slip-joint pipe. One-opening valves can be connected to two-opening, or vice versa, at any time by substituting a change of body. Ordinary 6-inch gate valves could be used, but the expense would be prohibitive, probably averaging four to six times as much as that of the low-pressure valves. The low-pressure valve of the above type is provided with a bell end, similar to the bell end of a terra-cotta pipe section, for cementing to the 6-inch riser in the same manner that one length of terra-cotta pipe is cemented to another.

Experiments made in distributing water in the grove near Orlando by means of these valves were very satisfactory. Short lengths of

portable 4-inch pipe were attached to each outlet of the valve by a flexible clamp connection. The pipe was constructed of 26-gauge galvanized iron, made in lengths of 20 feet. Adjustable gates for letting out the water were placed in the portable pipe 3 feet apart, thus permitting any desired amount of water to be let into each furrow. This was found to be a very great improvement on the type of gate first installed, as the sandy soil would not permit a good division of the water from a central point, since the furrows tended to flood together near the valve. This is prevented by the new arrangement. Both the valves and the small sliding gates in the

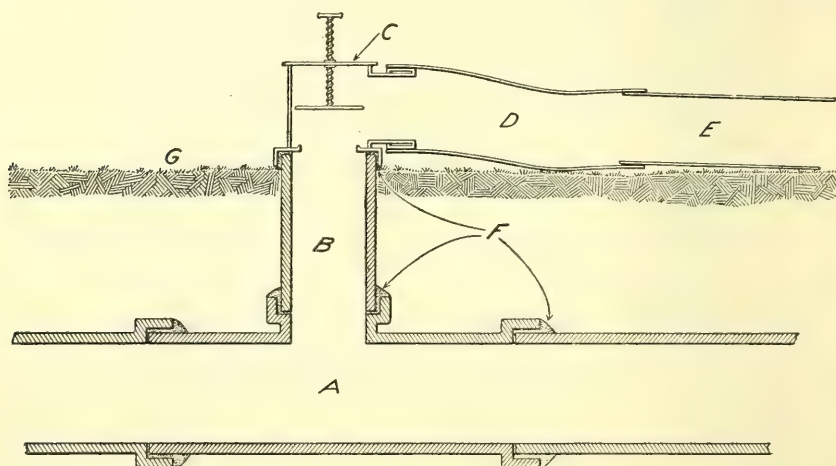


FIG. 10.—Cross section of irrigation valve, showing method of connection to underground terra-cotta main: A, Main terra-cotta pipe; B, 6-inch terra-cotta riser; C, cast-iron valve; D, connection hose; E, portable pipe; F, cemented joints; G, ground surface.

4-inch pipe have been improved, but the operating principle has been retained.

Another system involving the use of terra-cotta pipe is in operation in the grove near Palatka. This system was designed by the writer and installed in the summer of 1914. The engineer who supervised the construction has submitted the following report on the system:

The problem of efficient as well as economical irrigation, as applied to orange groves especially, has apparently been solved on the 50-acre grove at Palatka, Fla. On this project a flowing well of approximately 1,200 gallons per minute delivery furnishes the water supply, which is conveyed throughout the grove by 8-inch terra-cotta pipe. The pipe follows the contours of the highest elevations, forming a complete circle around the grove and leading back to the starting point, a standpipe near the well. (Pl. VI, fig. 1.) Six-inch low-pressure irrigation valves of cast iron are placed at intervals of 100 feet along the main line, the water being conducted to the trees by means of a slip-joint galvanized-iron pipe. (Pl. VI, fig. 2, and fig. 10.)

The plant is efficient, the water flows down the rows of trees guided somewhat by furrows and banks, and the cost of operation is practically nothing

but the cost of labor. The water supply is generous, friction being reduced greatly by the large main line.

In laying the terra-cotta pipe I met with the obstacle of inefficient labor, as there were only green negro hands available. By careful supervision, however, and by dividing the force in competitive gangs, the work was accomplished quickly and well.

As to cost, I shall give below a complete, detailed account which will show that we have put in an efficient irrigation system at the very low cost of \$28.86 per acre. Very fortunately the market price on terra-cotta pipe was quite low at the time of installation.

| | |
|---|----------|
| 5,000 feet No. 1 8-inch terra-cotta pipe, at \$10.50_____ | \$525.00 |
| Tees, bends, etc_____ | 25.59 |
| 500 feet 6-inch galvanized-iron, portable pipe_____ | 65.00 |
| Reinforcing and tapering ends of same_____ | 15.00 |
| 50 6-inch cast-iron irrigation valves, at \$3.50_____ | 175.00 |
| 14 barrels of cement, at \$1.80_____ | 25.20 |
| 225 pounds of spun oakum_____ | 17.50 |
| One 6-inch standard gate valve_____ | 9.75 |
| 63 feet of 6-inch black pipe (iron) and fittings_____ | 34.64 |
| Labor of laying pipe, ditching, and erecting standpipe--- | 250.39 |
| <hr/> | |
| Total_____ | 1,143.07 |

This list is complete and includes the entire outfit ready to use.

The terra-cotta pipe has many attractions for this low-pressure irrigation work. It is practically everlasting, easy to lay, and withstands the chemical action of the Florida sulphur water that ultimately destroys iron pipe. The extreme difference of elevation on this plant is 15.9 feet. The pipe stands the pressure with ease, but for a matter of precaution, in case the flow were turned on with all outlets closed, a standpipe is erected at the lower end of the line, with the elevation of the top 2 feet above the highest point in the pipe line. The water from the well flows through a 6-inch cast-iron pipe, which is the base of the standpipe. This base is of concrete in the form of a hollow square, with 8-inch pipe-line outlets. The standpipe is built of 12-inch terra-cotta pipe.

On the whole, I would say that a system such as I have briefly described is absolutely practicable and most economical as regards installation and upkeep and as efficient as any.

It will be seen from the above description that the system differs from the Orlando installation in many respects, particularly as to the method of distribution. The Palatka grove depended somewhat on the use of portable pipe, which will be used where the water can not be run by gravity. The valves are placed 100 feet apart instead of in every tree row, which means that the portable pipe will be required between the valves even where the grades are adapted to the furrow methods. These valves are the one-opening type of the 6-inch size, each capable of discharging several hundred gallons of water per minute. The terra-cotta relief stand is as good as a concrete box and much cheaper, but does not permit the installation of sliding gates as does the type used in the Orlando grove, nor does it

allow the installation of a weir for the measurement of water for experimental purposes, which is done in Orlando.

The Palatka plant could have been constructed without the portable pipe but at considerably higher cost, as the land is more uneven than that in the Orlando grove. This disadvantage might have been overcome, however, by the use of additional underground piping. It would have been necessary also to have placed a two-opening valve at every second tree row, which would have called for an additional expenditure. It will be possible to install these improvements at a later date if desired. The present system will answer the purpose well but requires more labor for its operation.

The following specifications, prepared by M. B. Williams, irrigation engineer, should be insisted upon when terra-cotta pipe is bought from dealers, as it is of the utmost importance to get the best pipe:

1. All pipe and specials shall be of the best quality standard vitrified salt-glazed terra cotta, sound and well burned, impervious to moisture, free from cracks, flaws, blisters, or other imperfections. All pipe shall be straight in the direction of the axis. Variations from a straight line greater than 2 per cent of the length of the pipe or from a true circle greater than 4 per cent of the diameter of the pipe will not be permitted.

2. Each pipe shall be of the hub-and-spigot pattern, with deep and wide sockets. Each hub shall be of sufficient diameter to receive to its full depth the spigot end of the next following pipe or special without any chipping of either and leave an annular space of not less than one-half inch all around for a mortar joint. Each hub shall have a depth from its face to the shoulder of the pipe not less than the following: 6-inch pipe, $2\frac{1}{2}$ inches; 8-inch pipe, $2\frac{3}{4}$ inches; 10-inch pipe, $2\frac{3}{4}$ inches; 12-inch pipe, 3 inches; 15-inch pipe, 3 inches. The inside of the hub and the outside of the spigot of all sizes shall be grooved. All pipe shall be furnished in 3-foot lengths. All specials shall be furnished in 2-foot lengths.

3. On all T-branches the branch shall stand at right angles to the run, and have a bell or socket end.

All pipe and specials shall be delivered f. o. b. cars, and shall be subject to inspection there. Pipes or specials having fire cracks of any kind extending through the thickness and having a length greater than the depth of the hub or socket shall be rejected. Air checks appearing only on the outer surface or in the glaze of the pipe will not be objectionable, but the use of a pipe having air cracks extending through the shell caused by too rapid cooling, will not be accepted. No pipe shall be accepted that has a piece broken from the spigot end longer than the hub or socket; nor which has a piece broken from the bell end if the fracture extends into the body of the pipe, or if such fracture can not be placed at the top of the pipe. All pipe shall give a clear-sounding ring when tested with a light stroke with a hammer.

The following specifications were prepared for laying the pipe:

All terra-cotta pipe should be laid below frost and covered with not less than 15 inches of earth. Trenches should have the following width of bottom for convenient laying and jointing of the pipe:

| | | | | | | |
|----------------------|----------|----|----|----|----|----|
| Size of pipe | inches.. | 6 | 8 | 10 | 12 | 15 |
| Width of ditch | do..... | 20 | 24 | 28 | 30 | 34 |

Begin laying pipe at intake end, with socket end of the pipe pointing forward. Round out bottom of trench to fit body of pipe and cut roomy depressions for sockets and entrance of hands in making joints.

Place rope of oakum around spigot end of each pipe and shove pipe and oakum together into socket. Prevent oakum from getting between end of pipe and shoulder of socket. Oakum is used to center the spigot in the socket and prevent the mortar from working inside of the pipe line. Drive oakum against the socket shoulder with a hand tamper. Lay several hundred feet with oakum before mixing joint mortar, taking care that each joint has a complete, even, annular space for mortar.

Mix joint mortar one part of Portland cement to one part of clean, sharp, fine sand. Mix the materials dry until they have uniform color, then wet to a stiff consistency which will permit the mortar being driven into the joint with an iron hand tamper without pressing out at any point.

Place mortar in joints, using light-weight rubber mittens, tamp firmly, making sure lower side of socket is filled, trowel off mortar, making a smooth shoulder, and immediately cover joint with moist earth.

Completely fill trench before rain occurs to prevent trench filling with water and floating the pipe line.

If the above specifications are followed there will be no trouble from leaks, provided the sand and cement are of good quality and care is exercised to prevent excessive pressure on the pipe. It must be remembered that this is low-pressure pipe and the design should take this into consideration. It is a safe rule to keep the pressure head between 5 and 15 feet. There should be a relief stand at some convenient point, and if the grove to be watered is a large one, it may be necessary to have several of these.

In determining the size of terra-cotta pipe to be used it should be remembered that to obtain the same flow through a small pipe that may be obtained with one of larger size will call for increased pressure. Approximate friction factors which are sufficiently close for preliminary estimates can be found in most of the pump or pipe catalogues published by various manufacturers. The following may be taken as an example: The friction of 500 gallons per minute through an 8-inch pipe is about equal to 0.6 foot per 100 feet of length. Thus, if 1,000 feet of this pipe were laid on a level, a pressure equal to 6 feet of head would be required to force the 500 gallons through the line. This would call for a pressure equivalent to a column of water 6 feet high at the intake of the pipe. An extra head of 3 to 5 feet should then be added to force delivery of the water. The factors of length and elevation must be considered carefully, and the services of an engineer should be obtained before the sizes of pipe to be used are finally decided upon. As a rule, nothing smaller than the following sizes of terra-cotta pipe should be used for the discharges indicated:

TABLE 3.—Size of terra-cotta pipe according to amount of discharge of water.

| Quantity of water.....gallons per minute.. | 300 | 500 | 1,000 | 1,500 | 3,000 |
|--|-----|-----|-------|-------|-------|
| Size of terra-cotta pipe to use.....inches.. | 6 | 8 | 10 | 12 | 15 |

If the length through which the whole amount of water is to be conveyed is more than 1,000 feet it will be well to increase the size of the line. It probably will be necessary to put in a few lengths of iron pipe instead of the terra-cotta whenever the head exceeds 15 feet.

Other low-pressure pipe used with success in Florida is of the continuous concrete type. A grove in Terra Ceia is equipped with a system of this design which irrigates about 60 acres, and there is a plant of like design and capacity at Dunedin. This does not take the place of the terra-cotta pipe, however, as it is not made in sizes over 3 inches, and a 3-inch pipe is of little utility with the furrow methods considered above. Continuous pipe has, however, given excellent results when used in connection with artesian wells at Terra Ceia and with iron pipe and sprinklers at Dunedin.

Prices of terra-cotta pipe vary, but the average is about as follows, delivery being to central Florida:

TABLE 4.—*Prices of terra-cotta pipe.*

| | | | | |
|----------------------------|----|----|----|----|
| Size.....inches.. | 6 | 8 | 10 | 12 |
| Price per foot.....cents.. | 10 | 15 | 19 | 25 |

Only a general idea as to total costs may be obtained by these prices.

The cost of laying the pipe also varies greatly, depending on labor and materials, soil conditions, and sizes laid, but will average from 2 to 5 cents per foot.

The complete cost of a distribution system of this type will vary for the average grove from \$20 to \$50 per acre, the average probably being about \$35 per acre. This does not include the pumping outfit or the iron main to the standpipe. Even if the higher figure is taken it will be seen that a great saving is made on the cost of the average distribution system now in use upon the sandy groves where the iron pipe and hose systems are in use. The average cost of the latter systems probably is \$100 to \$150 per acre, and many of them deliver no more than a fraction of the quantities of water required.

SOME IMPORTANT POINTS IN THE DESIGN AND EQUIPMENT OF AN IRRIGATION PLANT.

The first consideration for prospective irrigators is the water supply. Practically every section of Florida can be watered easily either from wells or from lakes or streams. Estimates as to the size and probable depth of a well should be obtained from local well drillers or from the State geologist, as conditions vary greatly. The cost of a well will depend mainly on its size and depth.

The area to be irrigated is the next item to consider, this and the capacity of the water supply being the determining factors in the

size and capacity of the pumping unit. The crop to be raised also must be taken into account, as must the methods which will be employed in distributing water. If the water supply is adequate and a 100-acre grove is to be irrigated it is evident that the plant should be of such capacity as to irrigate the whole grove within a reasonable time in order to obtain maximum service from the plant. This is true also for the 10-acre grove or the 1-acre truck patch. For the irrigation of a grove the surface methods probably would prove most satisfactory, and an irrigation equivalent to not less than two inches of rain should be figured on. A truck patch should have about the same amount for furrow irrigation, and about one-half of this if spray methods are employed. Another important factor to be considered in determining the necessary capacity of the plant is the time the farmer desires to consume in watering the grove. If he is willing to irrigate 24 hours a day he can get along on half the amount of water needed per minute in a day half as long. But night irrigation by surface methods seems to be unpopular in Florida and it will be best to figure on a 12-hour irrigation day. The personal element also enters into the number of days of irrigation required to cover the grove, but it is doubtful if a plant can be considered efficient if it will not furnish enough water to cover the grove in 10 days. This period is a good standard for use in Florida.

If 2 inches of water is to be applied to a 100-acre grove in 10 days of 12 hours each, the problem of figuring the gallons per minute is a simple arithmetical one; and this is equally true whether the grove contains 52 acres or 7 acres. There are 27,154 gallons in an acre-inch. Considering loss in transmitting and other losses while irrigating, it is better and easier to say that it requires 30,000 gallons of water to cover 1 acre 1 inch deep, or 60,000 gallons 2 inches deep. In the 100-acre grove it is necessary to apply 200 acre-inches, or 6,000,000 gallons of water. If this is done in 10 days, or 120 hours, or 7,200 minutes, a pump having a discharge of $\frac{6,000,000}{7,200}$, or 833 gallons per minute, will meet requirements. For any other acreage, gallons divided by minutes will give the capacity of the pump per minute.

Two acre-inches of water would answer for the furrow-irrigated patch if diversified truck crops which did not all need water at the same time were grown, but as the truck crops require a more rapid irrigation than the grove, owing to earlier injury from drought, it is well to double this estimate where such crops are to be watered. Irrigation by spray methods brings in other problems which can be solved readily, although they are of a different nature from those just discussed. For the spray plant it is advisable to figure on a

capacity equivalent to about 1 inch of rainfall per week for the entire area when the plant is running 5 to 8 hours per day.

Two general types of pumps are used in irrigation—high-pressure and low-pressure. The former are used in Florida for such plants as those using the high pressure overhead-spray systems and for many of the hose systems. The low-pressure systems, as a rule, are not used for exerting pressure over 20 to 30 pounds per square inch, but are employed extensively for irrigation purposes throughout the West and are the best design of pump for most surface methods as used in Florida.

The designs of pumps are innumerable, but two general types, the centrifugal and the displacement pumps, are most adaptable to Florida conditions. The centrifugal pump consists of a circular shell which incloses a swiftly rotating impeller. The water enters at the center of this impeller and is forced by the velocity imparted to the water by the curved fans of the impeller out of a discharge pipe leading from the outer edge of the shell. In Florida these pumps are used in the one-stage (having one impeller) and two-stage (having two impellers) types. The single-stage pump is built in sizes to lift any quantity of water to 75 to 125 feet. The two-stage pump will lift twice as high as a single stage. The single-stage pump is used for low-pressure work on surface systems and some spray systems of irrigation. The two-stage pump is used on several spray systems where the total head exceeds 75 feet.

Centrifugal pumps are, in general, most adaptable for pumping large quantities of water with the smallest installation cost. The efficiencies range from 30 to 65 per cent. They are built in many different forms to fit different water supplies, including wells. They are light in weight, require small space, seldom need repairing, have no valves, and are injured but little by grit in the water. These pumps should be placed as close to the water as possible and never exceed a suction lift of 25 feet. All air must be expelled from the pump case and suction pipe and these must be filled with water before starting. The speed must be proportional to the lift and quantity of water to be pumped.

Low-pressure centrifugal pumps range in cost from 1 cent to 5 cents per gallon per minute capacity. High-pressure pumps range from 5 cents to \$1.25 per gallon per minute capacity. The smaller the pump the higher the rate of cost per unit of capacity.

Displacement pumps lift water by means of a close-fitting plunger or piston traveling backward and forward in a cylinder equipped with valved openings. The best known displacement pump in Florida is the small, single-acting piston type used for domestic purposes, commonly called the pitcher pump, and usually operated by

hand. This type of pump is made with one (simplex), two (duplex), and three (triplex) cylinders. They are built to fit any type of water supply and in sizes to deliver any quantity of water for both high and low pressure. All three types mentioned are used in Florida with satisfaction. Displacement pumps are more costly than the centrifugal pumps, ranging from \$1 to \$4 per gallon per minute capacity, but the smaller sizes are much more efficient in many cases. These pumps range in efficiency from 50 to 75 per cent, but wear rapidly if there is grit in the water and need more adjusting and attention than centrifugal pumps to maintain their efficiency.

Practically the only types of power available in Florida are steam, gas, or oil. Gasoline or kerosene engines will be chosen in most cases, steam engines being used only where wood is cheap and the engine can be bought at a reasonable price. Electrical power in Florida is too expensive for use at the present time. The use of windmills is also impracticable for an area greater than a half acre, since a windmill requires the construction of a reservoir for irrigation purposes and a reservoir of sufficient size is more costly than a good pumping plant. Windmills are used for irrigation in the West, but soil conditions there permit the construction of cheap earth reservoirs, which is not the case in Florida. Current wheels and water wheels need not be considered here, as their use in the State is practically negligible.

The design of a pumping plant should not be undertaken by anyone unfamiliar with the technical factors entering into each case. The most certain method for a farmer to follow in obtaining a well-designed plant is to employ an engineer to make a survey and determine these factors, which should be submitted to several pump and engine dealers for their proposals. The proposals then can be compared and the most adaptable plant selected. The principal factors which the engineer should determine may be listed as follows:

1. The capacity and character of the water supply.
2. The kind of power to be used.
3. A description of the pumping site.
4. The type of distribution system to be installed and the pressure necessary to operate same.
5. The amount of water to be pumped per minute.
6. The elevation of the highest point of land above the water level when the pumping plant is running.
7. The length, type, and size of main pipe leading from the water supply to the point in the field where the water is to be delivered to the distribution system.

It is well to place these factors in the form of simple specifications and call for full descriptions and guarantees of the machinery proposed to be furnished, with prices quoted on the materials delivered at the nearest railroad station.

In conclusion, it has been seen that iron pipe is used in most distributing systems in Florida, but that this is often subject to rapid rusting. It is also expensive if large sizes are used, and if small sizes are used the plant is apt to be inefficient. It is not possible to avoid the use of iron or steel pipe for most of the spray systems, but the use of galvanized steel or galvanized iron pipe is advised for all overhead lines. If a low-pressure system is used for surface irrigation, it is practically necessary to have a high-pressure main pipe connect the pumping plant to the relief stand. This may be either cast-iron, wrought-iron, steel, or riveted steel pipe (black or galvanized). The cost of such pipe varies greatly, the cast-iron type being the most expensive but the most durable for Florida conditions. The riveted-steel pipe is cheapest, and will serve for a long time if well galvanized. It is probably unwise to install the asphalted or black riveted steel, as Florida conditions are very hard on such pipe.

A great deal of pipe has been taken up which has rusted out entirely in a few years. One experienced man reports that the lasting qualities of cast-iron, wrought-iron, and steel pipe are about in the ratio of five to three to one.

The size of the main will depend upon its length and the quantity of water it must deliver per minute. Most of the pumping plants in Florida will not need a main of more than 1,000 feet. For such conditions it would be well to keep within the following pipe sizes:

TABLE 5.—*Size of pipe required according to quantity of water to be delivered.*

| | | | | | | | | | |
|-----------------------------------|----|----|-----|-----|-----|-----|-----|-------|-------|
| Capacity.....gallons per minute.. | 10 | 30 | 100 | 250 | 300 | 450 | 600 | 1,000 | 1,500 |
| Size of pipe.....inches.. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 |

If smaller sizes are used for the corresponding capacities it will be necessary to increase the horsepower very materially to deliver the required quantity of water.

Finally, it will be seen that the saving effected by the installation of low-pressure pipe for furrow irrigation means not only a great saving in the distribution system but also a saving in the pumping outfit, on account of the reduced friction in the pipe system. If the power is not increased to compensate for the smaller pipe systems, the result is a diminution of the quantity of water to be delivered and a corresponding interference with the whole purpose of erecting and operating the irrigation plant, which is, of course, the delivery of sufficient water to prevent loss from the lack of moisture in the soil.

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EARTH, SAND-CLAY, AND GRAVEL ROADS

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Senior Highway Engineer.

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According to recent statistics gathered by the Office of Public Roads and Rural Engineering, the aggregate length of all public roads in the United States is, roughly, two and one-half millions of miles. Of this total mileage, earth roads comprise about 89½ per cent, or considerably more than 2,200,000 miles; sand-clay nearly 2 per cent, or 44,000 miles; and gravel about 4½ per cent, or 116,000 miles, which leaves only about 4 per cent, or about 110,000 miles, for all other types combined. The statistics also show that in the 10 years from 1904 to 1914 the increase in the mileage of improved roads, other than earth, sand-clay, and gravel, has been only from 2 to 3 per cent of the total, and that in States having the greatest mileage of improved roads, only about one-half of their aggregate mileage has yet been improved. From these figures it is evident that the construction and maintenance of earth roads will continue to be of considerable importance in connection with every comprehensive plan of public road improvement. Also, since sand-clay and gravel surfaces often constitute the first steps from earth roads toward the more highly improved surfaces, either one or both of these simple types may be expected to constitute in the future, as at present, no small part of the total improved mileage in practically every community. On account of this wide distribution of earth roads and their close relationship to sand-clay and gravel surfaces, public interest in these three types is both genuine and general and gives ample warrant for

the issuance of this bulletin, the aim of which is to supply reliable information concerning the construction and maintenance of earth, sand-clay, and gravel roads.

LOCATION AND DESIGN.¹

Since nearly all public roads are laid out originally as earth roads, and since the original location and design usually have such an important bearing on all subsequent improvements, it seems well to include in this bulletin a brief discussion of the fundamental principles underlying the proper location and design of a public road. But, before undertaking such a discussion in detail, it is desired to emphasize the all-important facts that for a particular road the best and most economical location depends largely upon individual judgment, and that well-balanced and experienced judgment regarding the relative importance of the various details involved is a much more valuable asset in undertaking to locate a road than mere technical skill in handling surveying instruments. No knowledge gained from books alone can give that complete grasp of the relations existing between a public road and the community it serves which is so necessary if the location and design of the road are to secure the greatest possible good from the money expended.

In locating or relocating a public road the prime considerations should be, first, the comfort and convenience of the traveling public which it is intended to accommodate; and, second, the economy of public funds. The first consideration fixes the general location of the road and limits such details of design and layout as affect the safety and comfort of travelers. The second should control the detailed working out of a location to suit the topography or surface layout of the region through which the road passes, with due regard for such features of the design as affect the cost of construction, of maintenance, and of hauling over the completed road.

The comfort and convenience of travelers require, first, that the road pass conveniently close to the dwelling places of those for whose particular use it is built; second, that it be free from dangerous curves and grades and sufficiently wide for safe travel; and, third, that the surface be such as to remain reasonably firm and smooth and to become neither very dusty nor very muddy under any combination of weather and traffic conditions. The extent to which any particular road must meet these requirements depends, of course, on the state of public sentiment in the community which pays for the road. But in most communities it is safe to assume that the standards of excellence as regards the accommodation demanded of

¹ This section has been read and revised by P. St. J. Wilson, chief engineer, and T. Warren Allen, general inspector, U. S. Office of Public Roads and Rural Engineering.

public roads will be raised rather than lowered. Due foresight, therefore, should be exercised in working out the location and design of a road, so that later improvements, such as reducing grades, increasing the width of the traveled way, or constructing a better surface, can be made without the necessity of making expensive changes in the location or otherwise wasting any considerable part of the work already accomplished.

A few general rules regarding the location and design of public roads may be stated briefly as follows:

1. Avoid sharp curves in the road, because such curves are a menace to traffic. On light grades and level stretches the location should be preferably such that a traveler may see at least 200 or 300 feet ahead from any point on the road, and on steeper grades this distance should be increased if automobile traffic is to be reasonably safe. Where the view is unobstructed and the grade is practically level country roads of ordinary width may be curved to a radius of only about 200 feet without seriously inconveniencing traffic, but to safeguard against accidents the radius of curves located on grades should be preferably not less than about 300 or 400 feet, even if the view is perfectly open.

2. Provide ample width for vehicles to pass each other without leaving the traveled way. The question of proper width is discussed on page 11.

3. Bear in mind that if a road ever becomes of any considerable importance, its users probably will demand that all the steeper grades be reduced to the lowest maximum that would conform to the general topography of the region which the road traverses. The question of grades is discussed on page 11.

4. Avoid all unnecessary distance. Aside from the advantages to traffic of a short route, each mile of additional road involves a considerable extra yearly expense for maintenance, and this alone may warrant the extra expense of shortening the route when the road is constructed, provided that the decrease in distance does not materially increase the steepness of the grades.

5. Regard land lines only in so far as this may be done without decreasing the usefulness of the road or increasing its ultimate cost. The tendency in most rural communities is to locate all new roads along land lines, regardless of the suitability of the route, and this has been responsible for much waste in the past. Not infrequently roads located along land lines have been graded at considerable expense, and abandoned later when the community demanded a more highly improved road with better grades.

6. Give reasonable consideration to the pleasing features of the location. A large part of the travel on most country roads is for

pleasure, and the degree of pleasure experienced in driving is largely dependent upon the scenic attractiveness of the road.

7. Plan to avoid the necessity for subsequent changes in location. Such changes nearly always work hardship on some of those who have built homes along the road.

The actual procedure of laying out a road should be controlled very largely by the lay of the land which the road is to traverse. Where the country is comparatively level, for example, practically the whole problem, aside from proper drainage, may be to determine a reasonable balance between the desire to avoid unnecessary damage to farming land and the purpose to secure a reasonably direct route over good ground.

One of the most common problems in laying out a road in level country is to decide between continuing a circuitous route around cultivated fields or along rectangular land lines, and establishing a new diagonal route across the fields. Tables 1 and 2, showing, respectively, the area in acres occupied per mile by roadways of various width, with other relevant data, and the diagonal distances across rectangles of various lengths and breadths may be of some assistance in these cases.

TABLE 1.—*Areas occupied by roadways of various widths and cubic yards of surfacing material required for 1 inch loose depth.*

| Width of roadway in feet. | Area in acres per mile of length. | Area in square yards per mile of length. | Cubic yards of surfacing material required for each 1 inch loose depth per mile of length. | Width of roadway in feet. | Area in acres per mile of length. | Area in square yards per mile of length. | Cubic yards of surfacing material required for each 1 inch loose depth per mile of length. |
|---------------------------|-----------------------------------|--|--|---------------------------|-----------------------------------|--|--|
| 8..... | 0.97 | 4,693.3 | 130.3 | 30..... | 3.63 | 17,599.9 | 488.7 |
| 10..... | 1.21 | 5,866.6 | 162.9 | 36..... | 4.35 | 21,120.0 | ..... |
| 12..... | 1.45 | 7,040.0 | 195.5 | 40..... | 4.84 | 23,466.4 | ..... |
| 16..... | 1.93 | 9,386.6 | 260.6 | 50..... | 6.05 | 29,333.3 | ..... |
| 20..... | 2.42 | 11,733.3 | 325.8 | 60..... | 7.26 | 35,199.6 | ..... |
| 24..... | 2.90 | 14,080.0 | 390.9 | | | | |

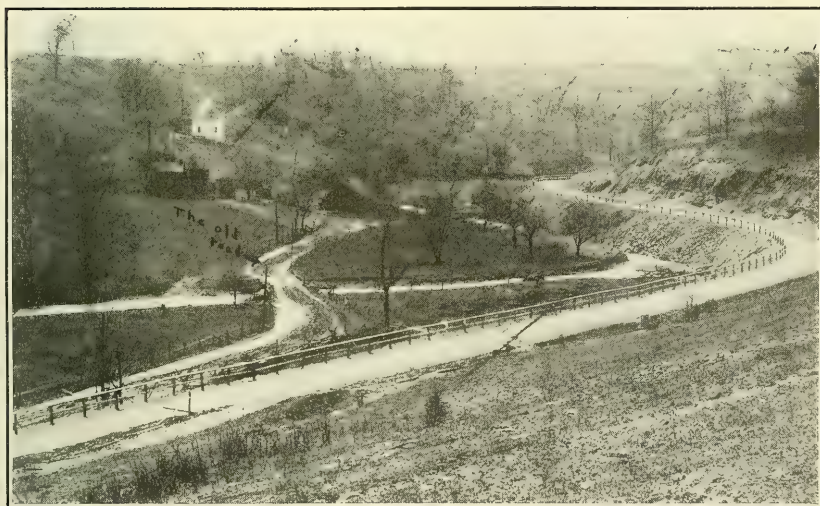
TABLE 2.—*Lengths of diagonals in miles for rectangles of various lengths and breadths.*

| Length of rectangle. | Breadth of rectangles. | | | | | | | |
|---------------------------|------------------------|---------------------|---------------------|---------|-----------------------|-----------------------|-----------------------|----------|
| | $\frac{1}{4}$ mile. | $\frac{1}{2}$ mile. | $\frac{3}{4}$ mile. | 1 mile. | $1\frac{1}{4}$ miles. | $1\frac{1}{2}$ miles. | $1\frac{3}{4}$ miles. | 2 miles. |
| $\frac{1}{4}$ mile..... | 0.353 | 0.559 | 0.790 | 1.031 | 1.274 | 1.520 | 1.767 | 2.015 |
| $\frac{1}{2}$ mile..... | .559 | .707 | .901 | 1.118 | 1.346 | 1.581 | 1.820 | 2.061 |
| $\frac{3}{4}$ mile..... | .789 | .901 | 1.060 | 1.251 | 1.457 | 1.677 | 1.904 | 2.135 |
| 1 mile..... | 1.037 | 1.118 | 1.250 | 1.416 | 1.607 | 1.802 | 2.015 | 2.236 |
| $1\frac{1}{4}$ miles..... | 1.274 | 1.346 | 1.459 | 1.600 | 1.767 | 1.952 | 2.150 | 2.358 |
| $1\frac{1}{2}$ miles..... | 1.520 | 1.581 | 1.676 | 1.802 | 1.952 | 2.121 | 2.304 | 2.500 |
| $1\frac{3}{4}$ miles..... | 1.768 | 1.820 | 1.904 | 2.015 | 2.150 | 2.304 | 2.475 | 2.657 |
| 2 miles..... | 2.015 | 2.061 | 2.136 | 2.236 | 2.356 | 2.500 | 2.657 | 2.828 |



OPPRE1917-BT

FIG. 1.—LOCATION OF ROAD FITTED TO GROUND SURFACE.



OPPRE3304

FIG. 2.—SHOWING WHERE RELOCATION WAS NECESSARY WHEN IT CAME TIME TO IMPROVE THE ROAD SURFACE. ALL WORK DONE IN GRADING THE OLD ROAD WAS ABANDONED.



In mountainous regions, on the other hand, the problem may be to fit the road to the contour of the country, regardless of land lines, cultivated fields, and all other considerations except grade, drainage, and line. Plate I, figures 1 and 2, illustrates methods of solving some common location problems where the lay of the land, or topography, was an essential consideration.

In general, the proper location and design of a road involves: (1) determining its controlling points; that is, fixing its general route with reference to certain points which the road must pass through, (2) surveying a route which passes through the controlling points and is otherwise adapted to the lay of the land, (3) a study of the drainage situation, (4) preparing such plans and drawings as are necessary for proper construction and a complete record.

CONTROLLING POINTS.

Such features of the locality as gaps through ridges, exposure to the sun, narrow stream crossings, and suitable points for crossing railroads (preferably by means of overhead bridges or under passes), together with the necessity for connecting up with certain centers of population, usually will serve to fix the location of a road within fairly definite limits. For important roads these controlling points are determined by careful inspection of all possible routes.

THE SURVEY.

The care which should be exercised in making a road survey necessarily must depend upon the importance of the road and the amount to be expended in its improvement. An ordinary farm road, for example, usually requires no survey other than lining it by the eye between the controlling points. Some unimportant public roads may require very little more than farm roads in the way of a survey, but if any considerable amount of grading or other work is to be done, either at the time the road is located or later, the survey should include all instrument work necessary to insure that the work will be done economically.

The purposes of a survey are (1) to determine accurately the topography or lay of the land so that the location may follow the route which presents the fewest obstacles, (2) to fit the grade line to the ground surface so as to keep down the amount of grading necessary, (3) to balance cuts and fills so that whatever grading is done will be to the best possible advantage, (4) to line up the road and provide stakes for controlling the work, (5) to obtain data from which proper plans may be prepared and an estimate of cost made, (6) to provide a record that will prevent subsequent contentions among landowners regarding the original location of the road. While the importance of all these purposes is apparent, frequently it

is not realized that they can not be accomplished except by means of a careful survey, and that such surveys can be made only by experienced men who have been trained especially for such work. Farmers and business men generally are inclined to underestimate the amount of skill required to make a road survey properly and their influence has been responsible in the past for much bungling and for uneconomical road work for which they have had to pay in heavy taxes.

Figure 1 illustrates an error which is made sometimes by inexperienced persons in grading a road without first having surveyed and planned the work. In this figure, which is an actual profile of an existing road, line A shows the original ground surface, line B shows the grade to which the road was actually constructed, and the dotted line (C) shows a grade line which, if it had been followed, not only

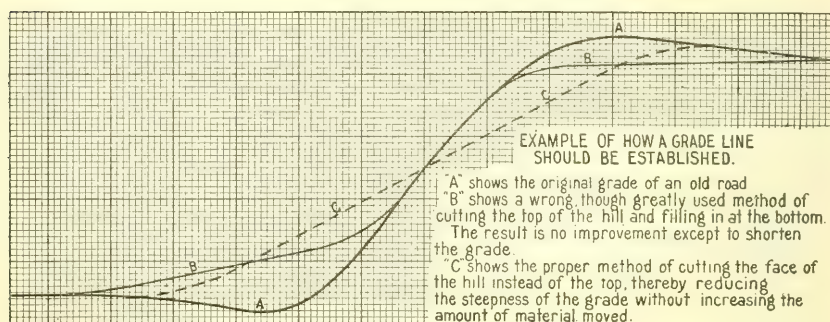


FIG. 1.

would have required no additional work, but would have reduced the steep grade materially and thereby improved the road considerably.

In fitting the grade line to the ground surface and balancing cuts and fills it should be borne in mind that earth, after being thoroughly compacted, will occupy less space in an embankment or fill than in its original position. The customary allowances for shrinkage and waste in road work are:

| | Per cent. |
|--|-----------|
| For heavy cuts and fills..... | 10 to 15 |
| For average grading..... | 15 to 20 |
| For light grading..... | 20 to 30 |
| For very light grading and considerable sod..... | 30 to 40 |

Solid rock will expand from one-third to one-half of its original volume when taken from a cut or excavation and placed in an embankment. But the spaces between the particles of stone should be filled with earth as the stone is being placed in the embankment. If this is done, no allowance should be made for the increase in volume when balancing cuts and fills.

DRAINAGE.

The subject of road drainage has been discussed at considerable length in other bulletins of the Office of Public Roads and Rural Engineering, and therefore will be given only brief mention here.

Effective drainage usually should be the very first consideration in connection with the location and design of any road. This statement requires no explanation, because the action of water in changing clay into mud and in causing all kinds of soils, except sand, to give way when a load is applied, is familiar to every person living in

SIDE DITCH

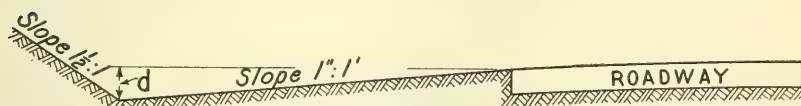


FIG. 2.

a humid climate. The following summary supplies a few suggestions as to how water may best be removed from a road bed:

1. The road surface should be crowned so as to shed water off to the side ditches as rapidly as it falls on the road. The typical cross sections (shown in figs. 15, 20, and 22) indicate the amounts of crown advisable under different conditions. These figures are supplemented by a discussion on page 9.

2. Wherever the road is in an excavation, suitable side ditches or gutters should be provided along the sides so that the water may

SIDE DITCH

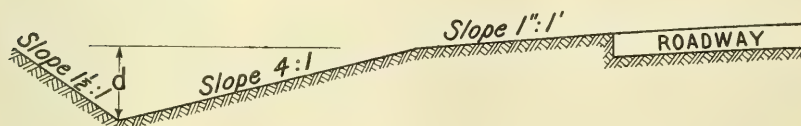


FIG. 3.

be conducted to some point where it may be turned off from the road. Figures 2, 3, and 4 show typical cross sections for earth side ditches. The cross section shown in figure 2 is suitable for steep grades where the depth of water in the side ditches must be kept low in order to prevent washing of the soil. Figure 3 shows a modified section which gives a greater capacity for the same widths of ditch than the cross section shown in figure 2, but which can be employed only on comparatively flat grades if washing is to be prevented. Figure 4 shows a cross section adapted especially to flat grades where a considerable volume of water must be carried. Ditches of the

cross sections shown in figures 2 and 3 have the advantage in that they may be constructed with an ordinary road grader, which is not true of the section shown in figure 4.

3. Where it is impracticable to construct side ditches that will carry the required amount of water without washing, paved gutters should

SIDE DITCH

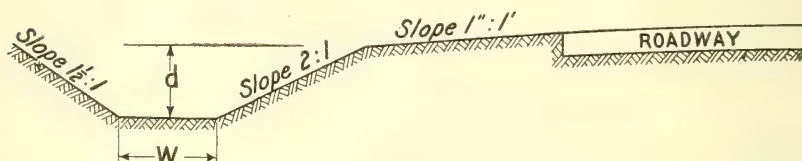


FIG. 4.

be employed. Suitable cross sections for a cobble gutter are shown in figures 5 and 6. Where it is impracticable to construct gutters, earth side ditches frequently may be kept from washing by the use of breakers (figure 7).

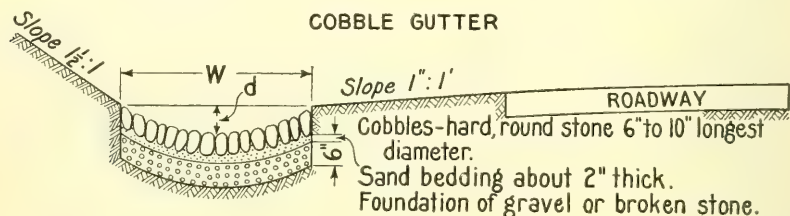


FIG. 5.

4. If the material composing the roadbed consists of springy earth, some form of underdrainage is essential. A line of farm tile laid to proper grade under each side ditch is, in general, the most satisfactory way of securing adequate underdrainage. Either 4-inch

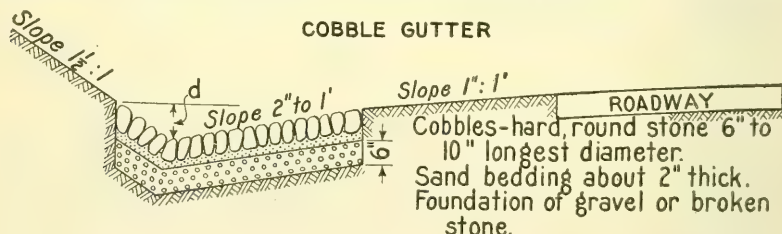


FIG. 6.

or 6-inch tile is employed for this purpose. Figure 8 illustrates the customary method of constructing tile drains.

5. Culverts or bridges should be constructed wherever it is necessary to carry water across the road. No rules regarding the planning of these structures can be given here.

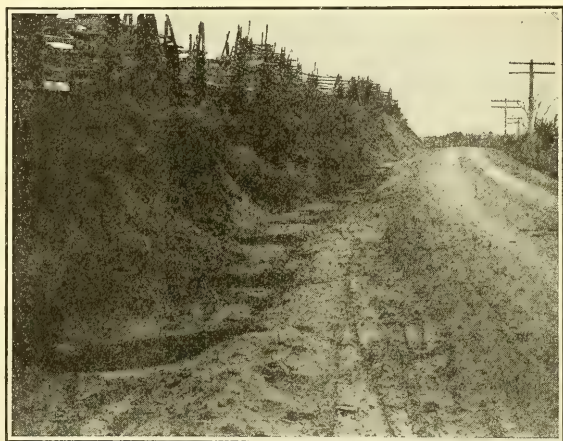
6. Avoid turning water from one intersecting road down the side ditches of another. Also avoid draining adjacent fields into the side ditches.

CROWN.

The proper crown to give the cross section of a road surface depends on two opposed factors:

(a) It is desirable to get water away from the surface as quickly as practicable, so as to prevent the surface material from being softened by saturation or washed away by water collecting in, and flowing along, ruts.

(b) It is desirable to keep the cross section of the road as flat as is consistent with good drainage, because traffic distributes itself over a flat road surface much better than over one that is heavily crowned, and an even distribution of traffic makes toward uniform wear and comparatively light maintenance. There is also less danger of skidding on a road of flat cross section than where the surface is crowned.



OPPRE12522

FIG. 7.—Use of wooden breakers to prevent scour of side ditch.

In general, the amount of crown should be greater on grades than on level stretches of road, because the tendency for water to wash away the surface by collecting in and flowing along ruts depends largely upon the steepness of the grade. Also the care with which a road is to be maintained may have an important influence on the amount of crown that should be given to the surface. It is evident that a road surface maintained in a smooth uniform condition will shed water off to the side ditches with much less crown than would be required where ruts are allowed to form.

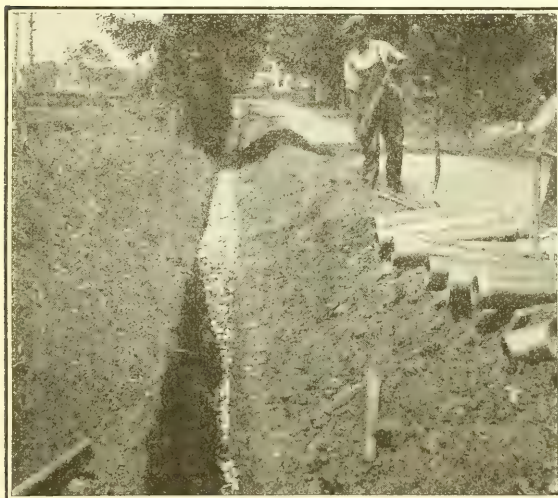
Instead of crowning the road surface sufficiently to prevent water from flowing along the traveled way and causing washes on steep grades, resort is sometimes had to "water breaks," or "thank-you-ma'ams," constructed across the road at short intervals. These water breaks may consist of either broad, shallow ditches or flat ridges constructed at a slight angle with the road so as to turn

water from the traveled way into the side ditches. Such devices usually are much more objectionable, especially to automobile traffic, than a rather heavily crowned road, provided the surface is not constructed of material which becomes very slippery when wet, and they should be dispensed with except in extreme cases.

An exception to the general rules for crowning a road surface perhaps should be noted as applying to cases where the roadbed and surface are of sand. In such cases it is preferable that the cross section be flat so as to retain as much moisture as practicable, though in cold climates a slight crown may be desirable in order to afford drainage when the surface is frozen. But sand roads must be surfaced with some other material if they are to be improved to any extent, and in that case the surface of the traveled way would have

to be crowned as usual. Also, where curves occur in the alignment it is desirable to "bank" or elevate the outer edge of the roadway and thus make the crown one way.

Bearing in mind the foregoing discussion, the crown limits indicated for the typical cross sections (shown in figs. 15, 20, and 22, respectively), should prove a fairly reliable guide in de-



OPRE12538

FIG. 8.—Constructing a tile drain, Montgomery County, Md.

termining the proper crown for earth, sand-clay, and gravel road surfaces under any set of conditions ordinarily encountered.

Figure 9 shows a cross section sometimes used for roads cut into side hills. The advantages claimed for this section are that whatever skidding occurs will be toward the hill rather than over the bank, and that the drainage water collected in the side ditch can be turned across the road at suitable points instead of being allowed to wash away the face of the embankment and perhaps damage abutting property. Except where short curves occur in the road, these advantages hardly seem sufficient to overcome the objection that all water falling on the upper portion of the surface must flow across the lower portion in order to reach the side ditch. Traffic naturally will seek the part of the road next to the hill, and this concentration of traffic, together with the additional water, will tend to produce mud.

WIDTH.

The minimum width to accommodate safely two lines of average horse-drawn traffic is 14 feet, and for automobile traffic the width preferably should be not less than 18 feet, though a width of 16 feet is used frequently. In order to maintain the traveled way to the required width and to afford proper safeguards against accidents, it is necessary to provide a shoulder not less than 3 or 4 feet wide along each side of the roadway proper. The shoulders may have a somewhat steeper crown than the rest of the road surface, as shown on the cross-section drawings, figures 21 and 22, but they should be sufficiently flat not to endanger traffic using them and really should constitute an additional width of roadway. This means that the total width of roadway between side ditches never should be less than 20 feet where horse-drawn traffic predominates, and 24 feet where any considerable volume of automobile traffic is to be accommodated.

Where sharp curves occur in the alignment it is desirable, though not customary, to increase the width of the traveled way. A vehicle being drawn along a curved road tends to occupy an appreciably greater width than where the road is straight, and unless the width

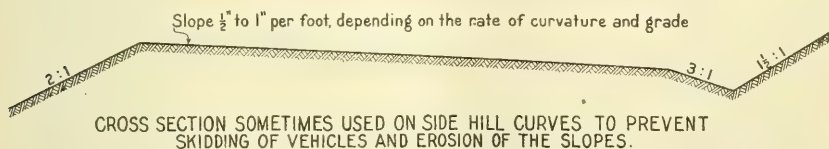


FIG. 9.

of the traveled way is increased correspondingly, this tendency contributes materially to the hazards that invariably accompany sharp curves. The minimum widths given above should also be increased on embankments of any considerable depth, so as to make maintenance easier and at the same time diminish the danger of accidents.

The width of right of way required to provide all necessary area for the roadway, slopes and ditches varies considerably with the nature of the topography. Where the topography is flat, or gently rolling, a 50-foot right of way usually will be sufficient for a 20-foot roadway. But where the country is very rolling or hilly the width of right of way usually should be at least 60 feet. For roadways wider than 20 feet it is usually sufficient to increase the width of right of way by the same amount that the width of roadway is increased.

GRADES.¹

In designing a public road one of the most difficult problems to solve properly is the question of maximum allowable grades. In

¹ E. B. McCormick, mechanical engineer, U. S. Office of Public Roads and Rural Engineering, has furnished the data on which this discussion is based.

deciding this question, the advantages to be gained by reducing all of the steeper grades on a particular road to a given maximum should be weighed against the additional cost which the reduction involves.

The following data and suggestions are intended to aid individual judgment, which necessarily must be the prime factor in solving this important problem:

1. The cost of average pleasure traffic, horse-drawn and motor, is practically unaffected by grades of not more than 6 or 7 per cent (6 or 7 feet rise per 100 feet, measured horizontally), provided the conditions are such that it is unnecessary to apply the brakes to vehicles when descending the grades. But for traffic where loads are as important as speed, even very light grades may be of considerable disadvantage.

2. Increasing the steepness of a grade decreases in three distinct ways the load a horse can haul: (a) for the same character of surface, the required tractive effort or pull¹ per ton of load is increased by about 20 pounds for each per cent increase in grade; (b) the possible pull the horse can exert is decreased by an amount equal to the effort required to lift his own weight through the rise; this amount is approximately equal to one one-hundredth of the horse's weight for each per cent increase in grade; (c) the effective pull of the horse is reduced by the change in the angle at which the pull is applied.

3. The pull a horse can exert on a level road varies greatly with the individual animal, and is affected by the manner of hitching and the skill of the driver. The character of the road surface also may have an important influence by affecting the security of the horse's foothold.

Tests² made by the Office of Public Roads and Rural Engineering indicate that, on a level road, average farm horses untrained to the road can exert a steady pull for several consecutive hours equivalent to from 0.08 to 0.10 of their own weight without undue fatigue, and that by resting at intervals of from 500 to 600 feet they can exert a pull equivalent to about 0.25 of their weight, provided the foothold is good.

4. The tests referred to above also indicate that with a well-constructed wagon the pull required to move a gross load of 1 ton over a level road varies about as follows:

| | Pounds. |
|--|---------|
| Loose sand road..... | 315 |
| Average dry earth road (varies greatly)..... | 150 |
| Firm earth or sand-clay road..... | 105 |
| Average gravel road..... | 80 |
| First-class gravel or macadam road..... | 55 |

¹ Pull is here used to mean the actual strain which a horse exerts against the whiffle-tree, and which might be measured by placing steelyards in the traces.

² These tests are not yet complete and subsequent results may cause the conclusions to be slightly modified.

5. Table 3 of loads is based on the foregoing statements, assuming the weight of the average horse at 1,200 pounds, the pull he is capable of exerting continuously for several consecutive hours on a level road at one-tenth of his weight, his maximum pull on a level road, over a distance not to exceed 500 feet without a rest, at twenty-five one-hundredths of his weight; and assuming that a proportionate part of a horse's energy is devoted to lifting his own weight on grades.

TABLE 3.—*Effect of grades on the gross load a 1,200-pound horse can haul.*¹

| Percent of grade. | Road through deep sand. | | Road over average dry earth. | | Road over firm earth or sand-clay. | | Average gravel road. | | First-class gravel or macadam road. | |
|-------------------|-------------------------|----------------|------------------------------|----------------|------------------------------------|----------------|----------------------|----------------|-------------------------------------|----------------|
| | Continuous load. | Maximum load. | Continuous load. | Maximum load. | Continuous load. | Maximum load. | Continuous load. | Maximum load. | Continuous load. | Maximum load. |
| | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> |
| 0..... | 760 | 1,905 | 1,600 | 4,000 | 2,285 | 5,715 | 3,000 | 7,500 | 4,365 | 10,910 |
| 1..... | 645 | 1,720 | 1,270 | 3,390 | 1,725 | 4,610 | 2,160 | 5,760 | 2,880 | 7,680 |
| 2..... | 540 | 1,550 | 1,010 | 2,905 | 1,325 | 3,805 | 1,600 | 4,600 | 2,020 | 5,810 |
| 3..... | 445 | 1,410 | 800 | 2,515 | 1,020 | 3,200 | 1,200 | 3,770 | 1,460 | 4,590 |
| 4..... | 365 | 1,275 | 625 | 2,190 | 780 | 2,725 | 900 | 3,150 | 1,065 | 3,735 |
| 5..... | 290 | 1,155 | 480 | 1,920 | 585 | 2,340 | 665 | 2,665 | 775 | 3,100 |
| 7..... | 160 | 950 | 250 | 1,490 | 295 | 1,765 | 330 | 1,965 | 370 | 2,215 |
| 10..... | | 700 | | 1,030 | | 1,180 | | 1,285 | | 1,410 |
| 15..... | | 390 | | 535 | | 590 | | 630 | | 675 |

¹ This table is based upon the assumption that for the same road surface the pull varies directly with the weight of the load. Tests to be made may make it necessary to modify this assumption.

Table 3 shows conclusively that for economy the maximum grade for any particular road should be fixed with due regard for the type of surface to be employed. For example, where the road is through deep sand, a horse of the character assumed, by extraordinary exertion, could pull his allowable continuous load of 760 pounds for level grades up a short grade of about 10 per cent, while in the case of a firm earth or sand-clay road the allowable continuous load for level grades is 2,285 pounds, and the steepest grade up which the horse could possibly pull this load is about 5 per cent. For average gravel roads the corresponding comparison would show a maximum grade of about 4 per cent.

Comparisons of the kind made in the preceding paragraph are not sufficient, of course, to determine the maximum allowable grades for any particular road, because, in general, the judgment should be largely influenced, in fixing the maximum grade, by the topography of the region which the road traverses. According to the best current practice, where the road is or is expected to become of sufficient importance to warrant a highly improved surface, the maximum grade usually is fixed with reference to this feature about as follows:

| | Per cent. |
|--|-----------|
| Coastal plain and prairie regions..... | 2 to 3 |
| Average rolling country..... | 4 to 6 |
| Hilly or mountainous regions..... | 6 to 8 |

The question of minimum grade is of importance only as regards the side ditches. These should have adequate fall to empty the water that collects in them at a sufficiently rapid rate to prevent damage to the road. Ordinarily it is desirable to give the side ditches a fall of about 1 foot per 100 feet of length, though a somewhat less fall has proved satisfactory sometimes.

Wherever changes in grade occur the change should be made by means of a vertical curve, and not by an abrupt angle.

SLOPES.

The slope at which earth will stand when faced up in a cut or placed in an embankment depends (1) on the character of the earth and (2) on the climate. In cuts, a good quality of nonslaking clay often will stand on a slope of about 45 degrees, or, as slope is expressed usually, 1 horizontal to 1 vertical, even where fairly deep freezing occurs, and in some of the Southern States such material has been known to stand for many years on a slope of less than one-half to 1. On the other hand, clay that slakes very easily may require a slope of 3 to 1, or even 4 to 1, under the most favorable condition of climate, but this latter extreme is very unusual. The usual slope for clay in cuts is 1 to 1 in warm climates and $1\frac{1}{2}$ to 1 in cold climates.

While in the case of embankments clay usually can be deposited on an initial slope of about 1 to 1, this steep slope seldom can be maintained unless the material is of an exceptional quality and the climate very favorable. Ordinarily clay embankments should have a slope of about 2 to 1 in cold climates and at least $1\frac{1}{2}$ to 1 in warm climates; and if the clay be of questionable quality these values should be increased. Embankment slopes require more care in construction than excavation slopes, because any flattening of an embankment slope by the action of weather after the road is completed is very likely to damage the road surface, while the sliding in of excavation slopes does no further damage than to obstruct the side ditches, which can be reopened readily.

Sand of average quality generally requires a slope of about 2 to 1 in cuts and 3 to 1 in embankments, regardless of climate. Moderately coarse sand mixed with gravel will stand on a steeper slope than fine sand, because the former is not moved so readily by the action of storm water.

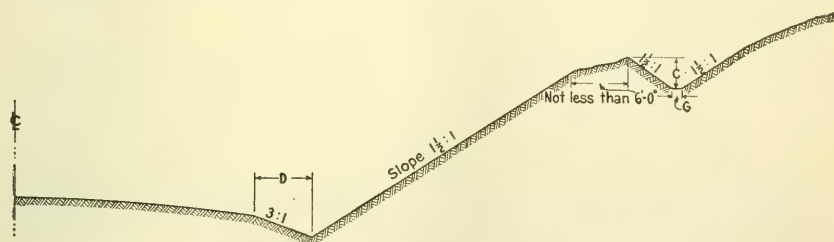
Solid rock excavation usually can be done on an average slope of about one-fourth to 1, except where the rock occurs in sloping strata separated by slippery clay seams. In the latter case the average slope may be as much as one-half to 1 or three-fourths to 1. The faces of rock cuts, as a rule, are not dressed down to even an

approximately smooth slope, as is done in earth cuts. In excavating solid rock only such material is moved as is actually necessary to obtain the desired width at the bottom of the cut or as has been loosened in blasting. The faces should, of course, be cleared of all material which is loose, or which might be loosened subsequently by frost and slide down upon the road. Stone embankments will stand on a slope of about 1 to 1.

In order to prevent damage by washing all earth slopes in either excavation or embankment should be protected by a growth of grass as soon as practicable after they are formed.

In many localities where the soil is fertile and a good quality of grass is native no seeding of the slopes is necessary. In other cases the soil may not possess sufficient fertility to grow grass, even when the slopes are seeded, and in which event it may be very desirable to cover the slopes with cut sod. This latter process usually is very expensive, and should be employed only where it is known that thorough seeding and fertilizing would fail to secure a covering of sod.

Another precaution frequently necessary in order to prevent the washing away of excavation slopes is to intercept water from the



CROSS SECTION SHOWING BERM DITCH BUILT ABOVE SLOPE

Dimensions of the ditch are determined by the amount of water to be carried.
 "C" is generally 18" to 24" and "G" about 12".

FIG. 10.

natural ground surface which otherwise would flow down over the excavation slope. This is done by means of a "berm" ditch constructed well back from the top of the slope. Figure 10 illustrates a condition which makes a "berm" ditch desirable and also shows how such a ditch is constructed.

EARTH ROADS.¹

Roads constructed by grading the natural soil to the required shape, grade, and alignment, without special surfacing of any kind, are designated as earth, or dirt, roads. The efficiency of such roads

¹ This section has been read and revised by P. St. J. Wilson, chief engineer, and T. Warren Allen, general inspector, U. S. Office of Public Roads and Rural Engineering.

depends (1) on the quality of the soil composing the roadbed, (2) on proper construction, and (3) on adequate maintenance.¹

SOILS.

The principal qualities of soils from the standpoint of road construction depend upon texture and structure, permeability, and capillary power. Soils usually are classified as clay, sand, loam, gravel, marl, or gumbo, according to the material predominating in their composition. Soils composed of two different materials mixed in such proportions that the character of the mixture is decidedly intermediate may be designated conveniently by naming both components, as sand-clay, sand-gumbo, gravelly clay, etc. Reference to Table 4, giving approximate bearing powers for different soils, will show that this classification may be of considerable significance in road construction.

TABLE 4.—*Approximate safe bearing powers for different soils.*

| Kind of soil. | Range of bearing power (pounds per square inch). | Kind of soil. | Range of bearing power (pounds per square inch). |
|---------------------|--|-----------------|--|
| Dry clay..... | 50 to 80. | Moist loam..... | 3 to 10. |
| Moist clay..... | 6 to 50. | Dry gumbo..... | 15 to 30. |
| Sand or gravel..... | 25 to 85. | Wet gumbo..... | 1 to 10. |
| Dry loam..... | 10 to 20. | Marl..... | Same as clay. |

CLAY.

Clay is a soil of very fine texture which results from the complete decomposition of rocks or minerals. Pure clay is very retentive of moisture and usually becomes plastic and unstable when wet, but when mixed with other materials, such as sand or gravel, its stability may be increased greatly. In general, a clay road, to be passable, must be kept dry, and since clay is very difficult to drain, it happens seldom that roads composed entirely of clay can be kept in good condition at all seasons of the year. No matter how well such a road may be graded and crowned the surface absorbs water in wet seasons and subsequent traffic will produce mud. But when the road is shaped and drained properly it will dry out quickly when the weather becomes favorable and may soon be restored to its original shape. On the other hand, clay roads, when very dry, usually produce considerable dust under traffic, and for this reason may become very insanitary in extended dry seasons.

The extent to which clay roads are subject to the objections mentioned above varies generally according to the so-called "slaking"

¹ Since the discussion of maintenance, as treated in this bulletin, will apply to the three road types under consideration, it has been placed after the chapter on gravel road construction.

qualities of the clay. Some varieties of clay, when compressed into a ball and placed in water, will continue in the original shape for a considerable time, even if thoroughly saturated and softened, while compressed balls made from other varieties will slake or break down almost immediately upon being placed in water. Clays of the first-mentioned variety are called "nonslaking clays," and of the latter, "slaking clays." It has been observed that slaking clays produce more mud in wet weather and more dust in dry weather than those of the nonslaking variety. This characteristic of clays is further considered in the discussion of sand-clay roads appearing in another part of this bulletin, where methods for testing clay are suggested.

Most clays, as they occur in nature, contain more or less sand or gravel, which, as pointed out above, usually has a stabilizing effect by making the clay more easily drained and increasing its bearing power when wet. In fact, a good quality of clay mixed with coarse sand in such proportions that the clay fills the voids in the sand and cements the individual particles together produces a soil which possesses the good qualities of both materials and which overcomes, to a great extent, the objections to each.

SAND.

Sand is composed of granular particles of mineral or stone which occur in nature and which will pass a $\frac{1}{4}$ -inch mesh screen. The $\frac{1}{4}$ -inch mesh screen is fixed arbitrarily as the dividing line between sand and gravel and is generally, though not universally, accepted as such. Nearly all sand consists essentially of quartz grains that are very hard and durable. But there is no coherence between the different grains, and therefore soils composed principally of sand are unstable, except when confined in some way. If properly confined and protected from undermining, sand foundations may, under favorable climatic conditions, prove entirely satisfactory for almost any type of road crust, but it is practically impossible, under any circumstances, to make a satisfactory road surface of sand alone. Dry sand offers almost as great resistance to traffic as mud, and except in very wet seasons sandy roads are likely to dry out to a considerable depth. The reason for this is that the capillary power of sand is comparatively low and the ground-water elevation may be lowered practically to the prevailing level of surface streams in extended dry seasons.

Sand roads are at their best when they are kept moist, and for this reason they should be designed with a view to retaining moisture in the sand rather than to effective drainage, as is the case with clay

roads. Such roads sometimes are improved temporarily by mixing sawdust, straw, pine leaves, or other similar material into the surface, but, in general, the sand-clay crust is the most satisfactory improvement for roads of this character. This is true especially where clay may be obtained readily and only limited funds are available for the improvement.

LOAM.

Loam is a soil composed of clay and sand, mixed with a considerable percentage of finely divided vegetable matter or humus. The quality of loam from the standpoint of road building depends very largely upon the proportions in which sand and clay are present and on the character of these materials. Loam that contains about 60 per cent of moderately coarse sand and from 20 to 30 per cent of good cementing clay usually will make an excellent road surface for light traffic. Material of this kind is drained easily and is fairly stable, even when wet. Another advantage is that it will not become very dusty under traffic in dry weather and frequently will cement together into a very hard, compact surface. Roads surfaced with such material are commonly called "topsoil" roads, because the topsoil of cultivated fields possesses the desired characteristics more frequently than that to be obtained from any other source. Topsoil is considered further in this bulletin in connection with the discussion of sand-clay roads.

GRAVEL.

Gravel is made up of small rounded particles of stone which occur in nature and are sufficiently large to be retained on a $\frac{1}{4}$ -inch mesh screen. Gravelly soils are distributed widely in the United States, and vary widely in quality. In general, when a soil contains as much as 40 or 50 per cent of gravel and sufficient clay or other cementing material to bond the gravel particles together, it proves a very satisfactory material for construction of roads, because it is drained easily and is very stable when compacted. The various characteristics of gravel are considered at much greater length in the discussion of gravel roads.

MARL.

Marl is clay containing a relatively large percentage of carbonate of lime. It grades into calcareous clay and argillaceous limestone, and its value for road building is variable. In general, this material has few advantages over the best varieties of ordinary clay for use in constructing a road, unless the percentage of lime carbonate is sufficiently high to give it, when compacted, approximately the character of limestone. The best varieties of marl become very hard

and compact when placed in a road surface, and in some localities this material is used extensively for road surfacing.

GUMBO.

Gumbo is essentially loam containing a high percentage each of clay and decayed vegetable matter and a very low percentage of sand. Gumbo has a strong tendency to absorb and hold water, and therefore is hard to drain. It is harder to handle in a road surface than clay, because the vegetable matter is an added weakness, but if protected from surface water by a proper system of drainage, it may be used to construct a fair subgrade for supporting some type of impervious road crust. Gumbo has a relatively high capillary power, and for this reason its occurrence in a road bed often will necessitate the use of subdrainage, even under conditions favorable for surface drainage.

CONSTRUCTION OF EARTH ROADS.

The work of constructing an earth road, after the general location and design have been decided upon, may be separated into six more or less distinct operations, viz:

(1) The work is staked out in accordance with previously prepared plans; (2) the right of way is cleared of all trees, brush, stumps, etc., which would interfere in any way with the work; (3) all necessary bridges, culverts, drains, and other structures which extend under the road surface are constructed in accordance with proper designs; (4) the roadbed is brought to the required width and grade by making excavations and constructing embankments; (5) the surface is finished to the required cross section and so maintained until compacted thoroughly; (6) all necessary outlet ditches, gutters, guard rails, fences, etc., are constructed in accordance with the plans.

STAKING OUT THE WORK.

Before any construction work is started on a road the limits of the work should be marked clearly by setting line and grade stakes at convenient intervals. The same stakes generally are made to serve for both line and grade, and the space between successive stakes is made 100 feet. Heavy reference stakes are driven on each side of the center line sufficiently far out not to be disturbed during the progress of the work. Then, as the work proceeds, such supplementary stakes as are necessary for marking the tops and bottoms of slopes, ditch lines, etc., may be set from the reference stakes by means of a string level and a metallic tape.

Culvert locations usually are fixed on the ground by means of two stakes in the line of the culvert, one near each end.

CLEARING.

After the work has been staked out the right of way should be cleared of all trees, stumps, brush, fences, etc., which occur within the lines of the work. Trees and stumps should be grubbed out or cut off at least 18 inches below the finished surface of the roadbed over them, and no parts of trees, stumps, or other perishable matter should be left in areas to be covered by embankments. Slightly trees that would not interfere with the work or obstruct the road in any way should be trimmed to a neat contour and left to afford shade.

CONSTRUCTING CULVERTS, DRAINS, ETC.

All drainage structures extending under the surface of the road should be completed, and the necessary backfills made over them before the work of grading is begun. There are two reasons for this. One is that usually less excavation will be required for such structures before the grading is completed than after, and the other that it is desirable to give the backfills as much time as possible to settle before the grading is completed, so as to avoid irregular settlement later.

The conditions under which culverts and drains are constructed vary to such a great extent that no attempt will be made here to discuss the detailed methods of construction.

GRADING.

The grading of an earth road includes all excavating, hauling, and filling necessary in constructing the roadbed, slopes, side ditches, etc., and usually is by far the largest item of work connected with earth-road construction. The most economical methods and machinery to employ in grading a particular road depend on the character and amount of the work to be done. Where, for example, the grade and cross section of the road follow closely the original ground surface most of the necessary grading usually may be done with a grading machine such as is illustrated in figure 11. In the case of embankments, built up with material from borrow pits along the sides of the road, an elevating grader (fig. 14) frequently may be used to advantage. If material must be moved longitudinally along the road from cuts to fills in order to bring the surface of the road to the required grade, the work usually must be done either with scrapers (figs. 16 and 17) or dump wagons (fig. 18). Where a considerable volume of material is to be excavated in a relatively short distance a small steam shovel (fig. 19) with dump-wagon equipment sometimes may be employed economically. Each of these methods may best be described separately.

USE OF GRADING MACHINE.

The grading machine illustrated in figure 11 is of the general design commonly followed in machines of this type. The heavy blade, which is 7 or 8 feet long and provided with a steel cutting edge, may be adjusted to any desired vertical or horizontal angle by means of hand wheels arranged conveniently about the operator's platform. Some of the best makes of grading machines are provided with attachments for such purposes as shifting the frame back and forth on the rear axle so as to adjust the blade to a desired position with reference to the wheel tracks, or to lean the wheels at an angle with the vertical and thus lessen the tendency of the machine to slide over a bank, or to

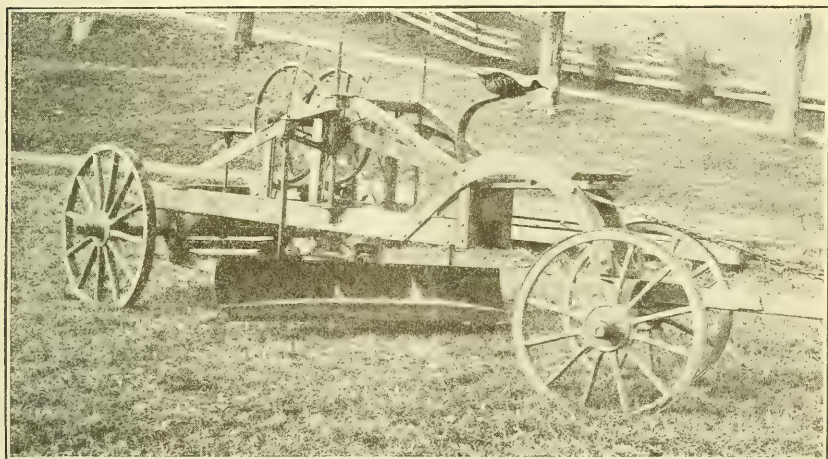


FIG. 11.—Grading machine.

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cut the rear wheels at an angle with the frame in order to overcome the tendency to slide when the blade is loaded. Most of the better makes of such machines are now constructed so the blade may be reversed entirely and the convex surface used for smoothing a road surface after it has been graded approximately to the required cross section. Machines of this type are made in different sizes and weights and cost from about \$175 to \$300 f. o. b. factory. The heavier sizes are best adapted for construction work and the lighter ones for maintenance.

A modified form of grading machine consists of a blade similar to that of the machine just described, which is supported by a simple frame on only two wheels. The 2-wheeled machine usually weighs only about one-fourth as much as the 4-wheeled type and costs considerably less, but the 4-wheeled type generally is to be preferred on account of its greater stability and also because it can be adjusted to meet a much wider range of conditions. In the following description

of the method of operation, therefore, it will be assumed that a 4-wheeled machine is to be used.

To operate a grading machine successfully where the work is moderately heavy requires at least six horses, while for light maintenance work after the road is graded four horses usually are sufficient. For satisfactory work the team must be accustomed to working together and must be under complete control of the driver. To break in a green team ordinarily requires two or three days of relatively very light work under favorable conditions and with a capable driver. Poorly trained teams and improper driving have been responsible for more unsatisfactory and uneconomical grading-machine work than any other one cause.

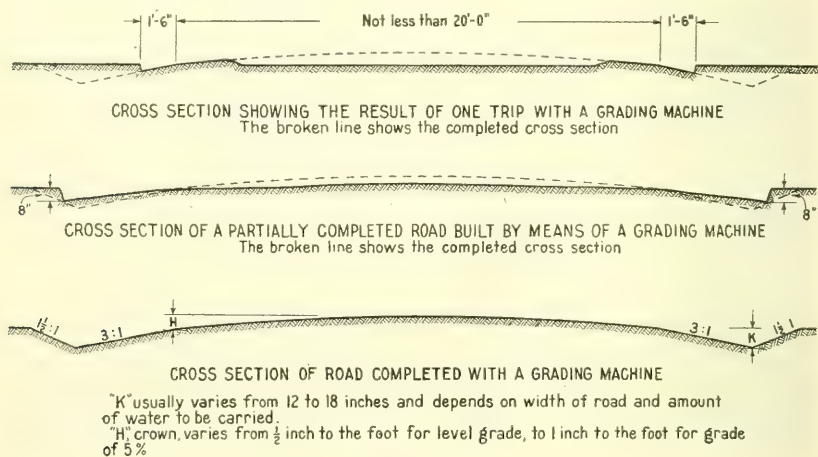


FIG. 12.

Before any machine work is done the area to be graded should be either burned or mowed over so as to remove all grass and weeds. The grading then should proceed as follows:

(1) Set a row of stakes, 100 or 200 feet apart, along the inside edge of each side ditch. The purpose of these stakes is simply to aid the driver in making the initial furrow of the machine conform with the line of the road, and since the stakes are destroyed by the first furrow they need be only sufficient to serve this temporary purpose. Figure 12 shows the successive steps involved in grading up a road with a grading machine after the ditch lines have been established as indicated.

(2) Set the blade of the grading machine at an angle of about 30 degrees with the road, so that the material loosened by the cutting point of the blade will be moved in toward the center of the road; also lower the cutting point and raise the heel, so that the blade will plow an initial furrow about 6 inches deep and about 18

inches wide. Then make the initial trip with the point of the blade cutting about 18 inches outside of the stake line and the outside rear wheel of the machine against the face of the furrow. The material loosened by the first furrow then will escape under the blade in a ridge just inside the stake line.

(3) Readjust the machine so that when the outside horses follow the initial furrow in making the second trip the blade will cut a new furrow of somewhat less width than the first and the outside rear wheel will follow the face of the new furrow. Then make successive trips with the machine adjusted in this way until the outside edge of the side ditch is approached, except that after each two trips it is well to rest the team by readjusting the blade and pushing the loosened material over toward the center of the road. For this latter work the blade may be set at a greater angle with the road, and the heel should be lowered and the point raised, so that the cutting edge will conform closely to the crown of the road while the machine is in operation.

(4) Repeat the above-described operation, omitting the stakes and beginning about 18 inches farther from the center each time, until the side ditches are excavated to the required depth and the road is approximately to the required cross section.

(5) Bring the outside faces of the side ditches to a uniform slope by making one or two trips of the machine with two wheels, one front and one rear, on the bank and the cutting edge of the blade against the slope.

(6) Make several trips over the road, cleaning out the ditches and smoothing up the surface. The last few trips should be made with the blade reversed, as this method tends to produce a better compacted surface. But, in any event, it is necessary that during the first few months after the grading is completed the road surface should be kept smooth while it is being compacted under traffic. To do this may require frequent use of the grading machine or the drag.

Plate II shows a model constructed by the Office of Public Roads and Rural Engineering for the purpose of illustrating in small space the successive steps involved in grading a road through level country by means of a grading machine.

The method of operating a grading machine described above necessarily will have to be modified at times in order to meet special conditions. Where, for example, the ditch area is covered with heavy sod or contains a number of large roots, it may be very desirable to plow this area and cut the roots with an ax before using the grading machine. If this is done the plow furrows should be turned toward the center of the road and the line of the initial furrows should be controlled by two rows of stakes as described above. If the sod is

very tenacious it should be harrowed with a disk harrow (fig. 13) ahead of the grading machine, and after the material has been moved over toward the center of the road the lumps of sod should be thrown out. A method sometimes followed is to skim off the sod, by means of hand shovels, ahead of the grading machine, but this method is expensive and seldom justified.

Whether or not it is necessary to contend with any considerable quantity of sod, the use of a disk harrow usually will prove helpful in securing a smooth uniform road surface with the grading machine. In general it is sufficient to give the loosened material a thorough harrowing after the road has been brought approximately to its required shape, but before the final shaping is done.



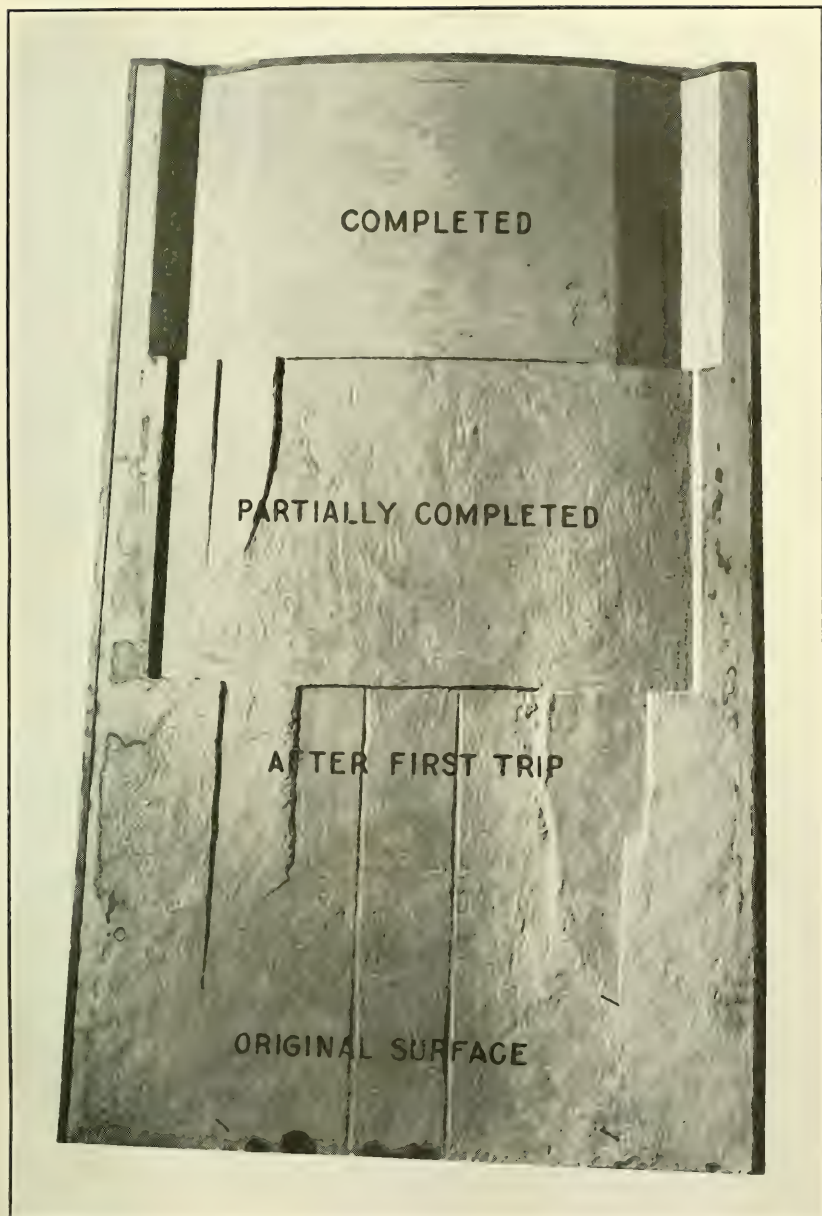
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FIG. 13.—Breaking up clods with a disk harrow.

Where continuous long stretches of road are to be graded with grading machines, it frequently is economical to substitute a traction engine for the teams and to employ two machines. Where this is done the first machine is connected immediately behind the tractor, either directly

behind or to one side, as the conditions require, and the second machine is connected behind and to one side of the first. Otherwise the method of operation is not essentially different from that already described.

The rate at which a road can be graded up with a grading machine varies to a great extent, and depends largely on the character of the soil. Where the original cross section of the ground is approximately level, such as that shown in the model (Pl. II), the cross section of the finished road similar to that shown in figure 12, and the soil conditions not unfavorable, a grading machine drawn by six well-trained horses should cut out the side ditches and shape the road in from 20 to 35 round trips. Allowing for a reasonable amount of lost time, the rate at which the team travels should average from $1\frac{1}{2}$ to 2 miles per hour, and under the circumstances assumed above, the length of road graded per day should average not less than one-fourth mile. Such favorable conditions seldom are found for any considerable stretch of road, except in the prairie sections of the



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EARTH ROAD MODEL, SHOWING RESULTS OF SUCCESSIVE OPERATIONS WITH GRADING MACHINE.

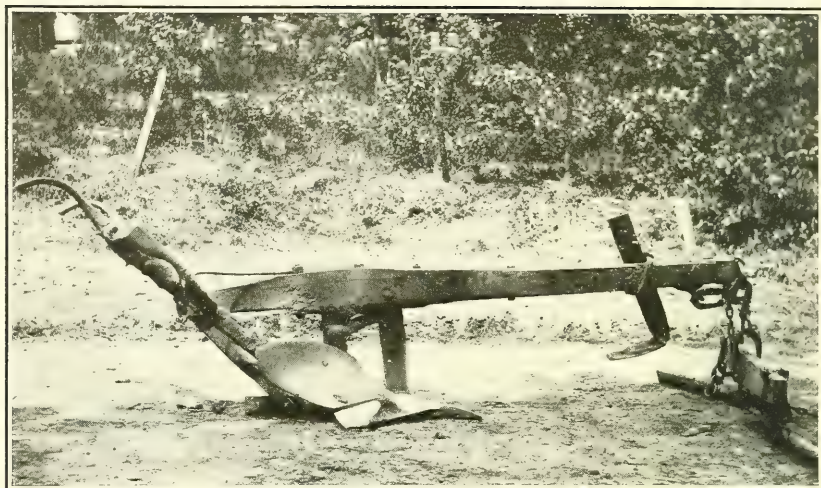


FIG. 1.—TURN PLOW.

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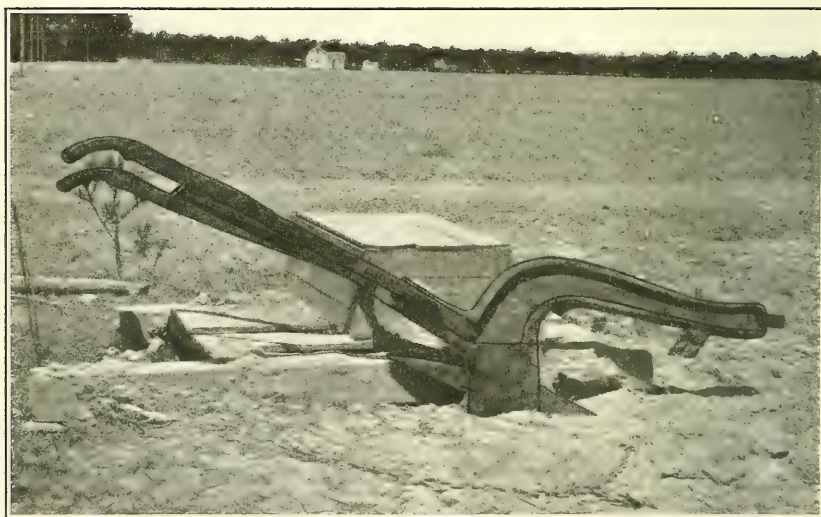


FIG. 2.—ROOTER PLOW.

Middle West, and the average rate of grading with a grading machine is, therefore, much less than one-fourth mile of road per day.

USE OF ELEVATING GRADER.

Figure 14 shows an elevating grader at work. The essential features of this machine are a plow with a heavy moldboard, an elevating belt, a suitable frame for supporting the plow and belt, and driving and adjusting mechanisms for operating the belt and controlling the work. The plow loosens the material and throws it onto the belt, which conveys and deposits it either in the roadbed or wagons.

Elevating graders are adapted especially to building up embankments with material excavated from shallow borrow ditches along



FIG. 14.—Elevating grader at work.

OPRRE572

each side of the road. They also may be used to advantage in excavating long, shallow, through cuts and loading the material thus excavated into wagons for use in building up embankments at other points. The latter use, however, is restricted to situations where there is sufficient space to operate the grader and at the same time afford passageway for the teams and wagons to follow under the end of the belt to receive the successive loads as the grader is drawn forward.

It is customary to employ a traction engine for operating the elevating grader, though teams are used sometimes. Ordinarily, the machine may be operated successfully either with a 25-horsepower tractor or with 12 well-trained horses. A well-constructed elevating grader, adapted to either horse or tractor power, may be purchased at an average price of about \$900.

The rate at which earth can be excavated with an elevating grader is relatively very high when conditions are favorable and the grader can be kept moving. But there are a number of rather complicated parts about such a machine which sometimes get out of order, and the work also is hampered frequently by many unforeseen contingencies, such as "bogging" of the wheels, choking of the plow or the elevator belt, occurrence of buried stumps or stones in the excavation, etc. For these reasons the actual capacity of elevating graders, considered over a long period, seldom is more than about one-third or one-half the rated capacity, and where the material is loaded into wagons as it is excavated the actual capacity of the machine may be reduced still further. Elevating graders of the size used ordinarily in road work have a rated capacity of about 100 cubic yards per hour.

USE OF SCRAPERS, WAGONS, ETC.

To grade a road of any considerable length, no matter where it is located, usually will require a considerable amount of work with devices other than the grading machine and elevating grader. The latter machines, as previously explained, may be very economical for special conditions to which they are adapted. But these special conditions seldom prevail for more than comparatively short stretches of road without sections intervening which require that a relatively large volume of material be moved from excavation to embankment within a distance of only a few hundred feet. Figure 15 shows a typical cross section for an earth road, where the grading

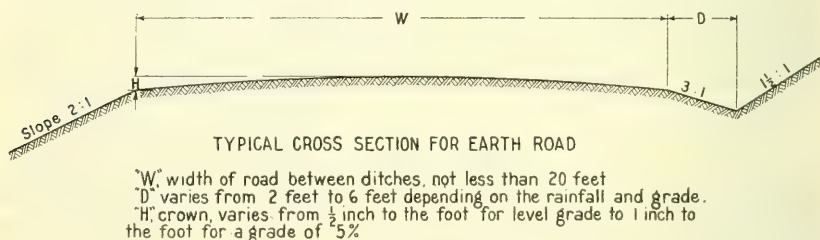


FIG. 15.

machine hardly could be used advantageously except for finishing the road surface. To accomplish work of this kind economically, the devices for loosening, loading, and hauling the material must all be adapted to turning around quickly in a small space and, not infrequently, must be such as to be handled readily over very rough ground. Such implements as wagons, wheeled scrapers, drag scrapers, and plows therefore should form a part of the equipment on practically all road-grading projects.

The choice of proper implements to employ in moving material from excavation to embankment depends, first, on the nature and quantity of the material to be moved, and, second, on the length of

haul. In general, where the material consists of earth it is loosened with plows and the economical method of hauling is fixed by the haul length about as follows:

For lengths of haul not exceeding 150 feet, drag scrapers; for lengths of haul between 150 feet and 600 feet, wheeled scrapers; for lengths of haul above 600 feet, wagons. Where the material consists of solid rock it must be loosened by drilling and blasting and practically always is hauled in wagons or carts, regardless of the haul length.

The two types of plows commonly used in road grading are shown in Plate III, figures 1 and 2. The former is the type generally used for loosening ordinary soils, while the latter is used for breaking up hardpan, old road surfaces and other earth unusually difficult to loosen. Either type is drawn by four horses, or in some cases by a traction engine, and is operated by three men, including the driver. Plows of the type shown in figure 1 of Plate III average about 150 pounds in weight and sell at an average price of from \$12 to \$18, but heavier plows of this type range in cost up to about \$30. With average soil conditions they may be made to turn a furrow about 7 or 8 inches deep and from 8 to 10 inches wide. The hardpan plows of the type illustrated in figure 2 of Plate III vary considerably in weight and selling price but cost more than the turn plows. One reason for the higher cost is that the points must be made of a very high grade of steel in order to be durable.

A drag scraper of the common type is illustrated in figure 16. Such scrapers are made in 1-horse, $1\frac{1}{2}$ -horse, and 2-horse sizes, which have respective rated capacities of 3, 5, and 7 cubic feet. Drag scrapers have an average weight, when empty, of from 75 to 100 pounds, and an actual capacity of about three-fourths the rated capacity. The price, f. o. b. factory, averages about from \$4 to \$6 per scraper.

In operating drag scrapers the drivers also may load and empty the scraper, but frequently it is economical to provide additional



FIG. 16.—Drag scrapers at work.

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laborers for this purpose. With a haul length of 100 feet and the teams moving steadily, one laborer should be able to load or empty and spread the material for about three scrapers. For scraper work to be effective the material to be excavated must be thoroughly loosened by the plows and should be free from large roots or stones. Where such obstructions occur time is saved by having them removed by hand during the progress of the plowing.

The average small organization for carrying on road-grading work with drag scrapers is made up about as follows:

Force:

- 1 foreman.
- 4 to 6 scraper drivers.
- 2 laborers for loading scrapers.
- 2 laborers for dumping and spreading.
- 1 driver for plow.
- 1 laborer to hold plow.
- 1 laborer for trimming shoulders, etc.
- 4¹ to 6 two-horse teams for scrapers.
- 1 or 2 two-horse teams for plow.
- Total, 1 foreman, 14 laborers, and 7 teams.

Tools:

- 6 drag scrapers (capacity 5 cubic feet).
- 1 road plow.
- 2 picks.
- 2 axes.
- 2 mattocks.
- 3 shovels.

The force employed should vary somewhat with the haul length, which is usually between 25 feet and 150 feet. Under average conditions an organization such as that described above should move from 300 to 350 cubic yards of earth per 10-hour day.

An objectionable feature of drag-scraper work is that the embankments tend to settle very irregularly. The reason is that the successive loads are not spread out uniformly as they are dumped, but are deposited as a succession of rather compact cores with the intervening spaces consisting of comparatively loose material. The loose material settles more than the compacted spots, and this unequal settlement produces pockets in the surface which hold water and gradually become deepened under the action of traffic. Where the material to be moved is loose and light, such as the prairie soils of the Middle West, this objection can be overcome largely by substituting Fresno or Buck scrapers for the common type of drag scrapers.

Fresno scrapers are made in several different sizes and range in capacity from about 8 to 12 cubic feet. They are drawn usually by three or four horses, and can be operated in almost as small a space as drag scrapers. Their average cost is from \$15 to \$20 each. One principal advantage of Fresno scrapers is that the runners may be adjusted to spread out the load to any desired depth from 2 or 3

¹ Where necessary, one of the scraper teams may be used to help the plow team.

inches up to 12 inches and this better distribution of the material in the embankment tends to prevent inequalities from developing in the finished road surface.

Wheeled scrapers (fig. 17) are used to a greater extent in road grading than either drag scrapers or wagons. The reason for this is that in road work the haul length falls, more frequently than otherwise, within the limits for which wheeled scrapers are economical. Several different sizes of such scrapers are in ordinary use, but the size employed most commonly has an actual load capacity of from 11 to 15 cubic feet, according to how heavily the load is heaped. Scrapers of this size ordinarily sell for from \$35 to \$50 f. o. b. factory.

In operating wheeled scrapers the material is loosened by plowing, in the manner already described, and is loaded by the scooping action of the scraper.

Two horses usually are sufficient to draw the scraper after it is loaded, but a second team, called a snatch team, is hitched in at the front of the tongue to assist in loading. The snatch team should consist of either two or three horses, according to the character of the material, and one snatch team should serve several

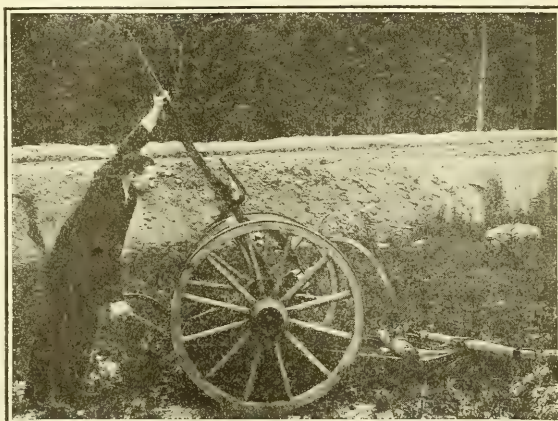


FIG. 17.—Wheeled scraper.

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scrapers. The loading and dumping of the scrapers are done by laborers provided for that purpose and not by the drivers.

A small organization for carrying on grading work with wheeled scrapers may be made up about as given below:

Force:

- 1 foreman.
- 6 to 11 drivers.
- 1 laborer for plowing.
- 2 laborers for loading scrapers.
- 2 laborers for dumping and spreading.
- 1 laborer to trim slopes, etc.
- 1 two-horse team for plow.
- 4 to 8 two-horse teams for scrapers.
- 1 or 2 two-horse snatch teams.
- Total: 1 foreman, 17 laborers, 11 teams.

Tools:

- 8 wheeled scrapers (capacity 11 to 15 cu. ft.).
- 1 road plow.
- 2 picks.
- 2 mattocks.
- 2 axes.
- 3 shovels.

The force employed should vary with the haul length, usually from 150 feet to 600 feet. Six to eight scrapers should be employed where the haul exceeds 250 feet. Where necessary one of the snatch teams may be used to assist the plow team.

Such an outfit should move from 200 to 250 cubic yards of earth per 10-hour day.

Several types of dump wagons are used in road-grading work. Probably the most common is the ordinary farm wagon fitted with a slat-bottomed bed as illustrated in figure 14. The most usual capacity for wagons of this kind is about $1\frac{1}{2}$ cubic yards. Patent dump wagons (fig. 18) are made in sizes ranging from 1 to 3 cubic yards capacity, and, in general, are preferable to the slat-



FIG. 18.—Dump wagon.

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bottomed wagons, because they are turned around more easily in a short space and are much more easily dumped. Patent dump wagons of the size employed ordinarily in road work ($1\frac{1}{2}$ cubic yards capacity) sell at an average price of about \$150, f. o. b. factory, which is a relatively high cost as compared to farm wagons, the price of which seldom exceeds about \$50 or \$75. One-horse carts are used sometimes instead of wagons, but two-wheeled vehicles

are very severe on horses, especially when hauling over rough ground, and therefore the use of carts is not recommended.

Where wagons are used for hauling and the excavation is fairly light, it is customary and economical to loosen the material with plows and to load it into the wagons with hand shovels. If the excavation is fairly heavy and sufficient in amount to warrant the additional outlay, it is economical sometimes to employ a small steam shovel (fig. 19) for loosening and loading the material. The steam shovels used ordinarily in road work have a dipper capacity of from one-half to three-fourths of a cubic yard. Under fairly favorable conditions steam shovels of these sizes can be made to load from 400 to 500 cubic yards of stiff earth per 10-hour day.

Where the material is loosened by means of plows and hauled in wagons the average small grading gang may consist of 1 foreman, 3 laborers, and 2 teams for plowing, 9 laborers for loading, 2 laborers for spreading, and a sufficient number of teams for hauling to

keep the above force busy. With such a force the number of wagons for maximum efficiency varies from about 3 for a 500-foot haul up to about 12 for a haul of 1 mile. Ordinarily, one of the plow teams may be employed in hauling for at least a part of the time.

Under average conditions such a force as that described above should move about 150 cubic yards of earth per 10-hour day.

BUILDING EMBANKMENTS.

One of the most important considerations connected with the grading of an earth road is the stability of the embankments. Where a road is situated in a cut and is well drained, it is not likely

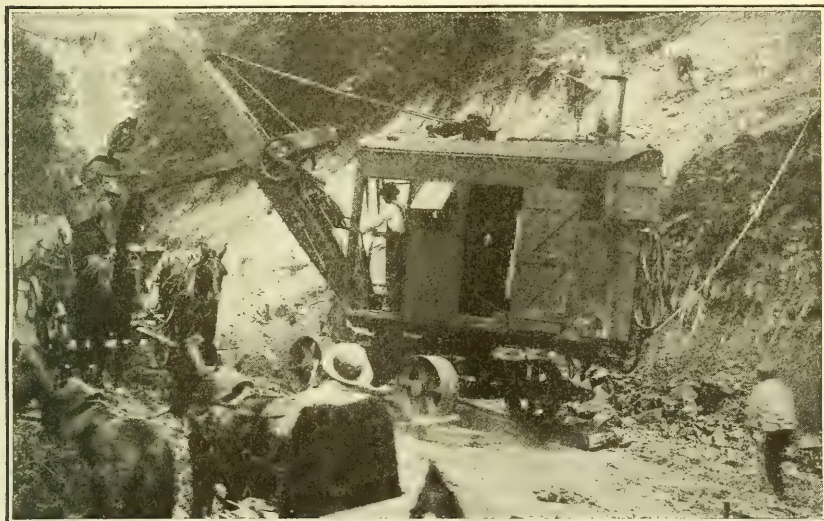


FIG. 19.—Steam shovel at work.

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to be affected seriously by such agencies as shrinkage, settlement, and slipping, any one of which may injure or destroy a road situated on a poorly constructed embankment. In grading a road, therefore, the methods employed in building the embankments are deserving of much more careful scrutiny than those employed in making excavations.

To prevent a road over an embankment from being damaged by shrinkage of the material forming the embankment, the material must be free from vegetable matter and uniformly compacted as it is deposited. Where the road surface is to be of earth, the embankment usually may be compacted sufficiently to prevent injury from shrinkage by spreading the material in relatively thin horizontal layers and letting each layer be compacted by the grading teams as the succeeding layer is being spread. Layers of ordinary earth, not

more than about 12 inches thick, can be compacted fairly well in this way, provided that the grading teams are made to travel over the entire surface of each layer, and that the material is spread uniformly. Where the road surface is to be of some highly improved type, each layer of the embankment should be rolled thoroughly with a power roller weighing not less than about 10 tons.

Settlement of embankments, aside from that due to shrinkage, may be caused by the gradual flattening of the slopes or by lack of stability of the ground surface over which the embankment is constructed. The question of proper slopes for various materials has been discussed. The question of ground surface stability usually does not arise as a grading problem except where an embankment is being constructed over very marshy land. If proper precautions are not observed, the embankment material may be absorbed gradually by the marsh until the entire roadbed has disappeared, an occurrence which is not infrequent.

Where drainage of the marsh is impracticable, the lower portion of the embankment, which would come in contact with the marsh water, should be formed of some nonslaking material that will cement together and distribute the weight of the embankment over the entire bottom area. Some varieties of gravelly clay are excellent for this purpose. Where the marshy matter is very soft and deep, it may be necessary to lay a wide foundation bed of logs, or fascines, upon which to construct the embankment, but such a foundation bed would not obviate the necessity for using a nonslaking material in the lower portion of the embankment.

Where embankments are constructed on very sloping ground, or where old embankments are to be widened, there always is a tendency for the new material to slip along the plane of separation. In such cases the old surface should be roughened before the new material is deposited. Where the old surface is earth, it usually can be roughened sufficiently by plowing a series of rather deep furrows about 2 feet apart. Old rock surfaces ordinarily are fairly rough to begin with, but to prevent slipping it may be necessary in some cases to blast steps into such surfaces before depositing embankment material.

Retaining walls, slope walls, and cribbing also are frequently used to prevent embankments from slipping.

FINISHING THE SURFACE.

No matter how the grading of an earth road may be accomplished it usually is economical to bring the road surface to its final shape by means of a grading machine. In making excavations it is not generally considered practicable to form the crown and side ditches

with scrapers or hand tools alone, and the cross section is, therefore, frequently left approximately flat. The grading machine is then used, in the manner already described, to produce the required cross section.

After the road has been finished with the grading machine, it should be given frequent attention until the embankments have finished settling and the surface has become thoroughly compacted by the action of traffic. Generally a period of several months should elapse after a road is graded before it is considered complete, and such settlements and irregularities as develop during this period should be corrected by the use of either a grading machine or a road drag. A description of the road drag and a discussion of its uses are given on page 58.

CONSTRUCTION COSTS.

Aside from drainage structures, the principal item of cost attached to the construction of an earth road is for the grading. The cost of grading varies greatly, according to the condition of the weather, the nature of the material to be excavated, the efficiency of labor, teams, and machinery, etc., and seldom can be estimated in advance with any great degree of accuracy. On this account average costs based on past experience may be very misleading when applied to a particular project. In the following statements and data an effort is made to show the approximate range of cost rather than the average.

The first step in estimating the cost of grading a given road is to ascertain the quantities of work to be done. After the quantities have been determined the cost may be estimated in either of two ways. First, the organization for carrying on the work may be planned in detail and the estimate arrived at by considering the cost of maintaining such an organization, together with the rate at which it may reasonably be expected to accomplish the work. Second, the cost per cubic yard for excavation and the cost per mile for shaping the roadway may be estimated at flat rates. The first method is the most accurate, though the latter is the one employed most frequently.

If the prices for labor and teams are known, the cost of grading under a given set of conditions may be estimated from the data already given. A frequent source of error in estimating costs in this way is that such items as supervision, lost time for which payment must be made, repairs to tools and machinery, and depreciation of the plant are overlooked.

The following data (Tables 5 and 6) are intended to furnish a rough guide in making estimates of grading cost at a flat rate per cubic yard. They are based on labor at 15 cents per hour; horses

at 12½ cents per hour. The depreciation of grading equipment and repairs are figured at 5 per cent per month while in use, and it is expected that the force will be organized economically and managed efficiently.

TABLE 5.—*Grading machine work.*

Assumed conditions: Original cross section flat; finished cross section similar to figure 12; team to consist of six to eight well-trained horses; no material moved longitudinally.

| Character of soil. | Cost per mile. |
|---|----------------|
| Light prairie free from stumps, roots, etc..... | \$60 to \$80 |
| Average clay loam..... | 100 to 150 |
| Heavy clay, moderate amount of sod and roots, plowing necessary throughout..... | 200 to 250 |
| Heavy clay, exceptionally difficult conditions..... | From \$250 up. |
| Crowning and shaping road which has been graded with scrapers, etc..... | \$50 to \$75 |

TABLE 6.—*Excavation and embankment.*

Assumed conditions: All material to be loosened with plows or by blasting, and to be moderately dry when handled; hauling to be done by means of drag scrapers, wheeled scrapers, or wagons.

| Kind of material. | Average haul length. | Method of hauling. | Average cost per cubic yard. | Remarks. |
|--|----------------------|-----------------------|------------------------------|--|
| | <i>Feet.</i> | | <i>Cents.</i> | |
| Light sandy loam, free from roots, etc. | 50 | Drag scrapers..... | 10 to 15 | Material assumed to be such that little or no plowing is necessary. |
| | 100 | do..... | 12 to 20 | |
| | 300 | Wheeled scrapers..... | 16 to 25 | |
| | 1,000 | Wagons..... | 25 to 40 | |
| Average clay loam, free from roots, etc. | 50 | Drag scrapers..... | 15 to 20 | Material such as to be loosened with plow drawn by two horses. |
| | 100 | do..... | 17 to 25 | |
| | 300 | Wheeled scrapers..... | 23 to 35 | |
| | 1,000 | Wagons..... | 32 to 50 | |
| Heavy clay..... | 50 | Drag scrapers..... | 18 to 25 | 4 horses required for plowing. |
| | 100 | do..... | 21 to 30 | |
| | 300 | Wheeled scrapers..... | 28 to 38 | |
| | 1,000 | Wagons..... | 40 to 55 | |
| Hard pan or loose rock. | 300 | Wagons..... | 40 to 65 | Low prices apply where material may be loosened with 4 horses and hardpan plow. High prices where blasting is necessary. |
| | 1,000 | do..... | 45 to 75 | |
| Solid rock..... | 300 | Wagons..... | \$0.65 to \$1.50 | High prices apply where stone is hard and excavation shallow. |
| | 1,000 | do..... | .75 to 1.75 | |

SAND-CLAY ROADS.¹

A road surface constructed of sand and clay mixed in proper proportions possesses the resisting powers of the sand in wet seasons and of the clay in dry seasons, and frequently is superior to either in all seasons.

Natural sand-clay soils occur to some extent in nearly all sections of the United States, and in many localities are rather widely distributed. Ordinary earth roads frequently contain short sections

¹ This discussion is based largely on information contained in Farmers' Bulletin 311, "Sand-Clay and Burnt-Clay Roads," which was prepared by William L. Spoon, senior highway engineer, and has been read and revised by E. W. James, general inspector, U. S. Office of Public Roads and Rural Engineering.

which are constructed of such soil, and it happens occasionally that for a considerable distance along a road the soil contains just the proper proportions of sand and clay to produce an excellent road surface for moderate traffic under all weather conditions to which the road is subjected. But, in general, such soils occur only for limited distances, and to secure a continuous surface of this kind, the necessary material must be hauled to the road, spread, and compacted after the grading is completed otherwise. More generally, perhaps, the soil composing the roadbed is deficient in only one of the necessary constituents, sand or clay, and it frequently may be economical to construct the surface by supplying the necessary sand or clay and mixing it with the natural soil of the roadbed, rather than to provide a surface of natural sand-clay material. It may happen, also, that the roadbed contains no material suitable for use in constructing the surface, and that sand and clay are more readily available separately than ready mixed. In such case both materials may be hauled to the road and mixed in place to form the surface.

In order to distinguish between common earth roads, which are constructed wholly of the natural soil as it occurs along the road, and those which have been surfaced with especially selected or especially prepared earth which contains sand and clay mixed in such proportions as to increase the resistance to wear of the surface as described above, the latter are designated sand-clay roads. This designation evidently includes most of the so-called "topsoil" roads, because topsoil which is especially suited for use in road surfaces generally possesses that quality by virtue of the sand and clay which it contains.

The sand-clay method of construction has produced its best results in the Southern States, where deep freezing is not a serious factor and where materials suitable for such construction probably are more widely distributed than in any other section of the country. There are many sand-clay roads in the South Atlantic and Gulf States over which heavy loads of cotton and other farm products are hauled throughout the year and which remain continuously in good condition with a comparatively very small outlay for maintenance. And there are innumerable cases where sand-clay surfaces, constructed of even rather inferior materials, have so improved intolerable stretches of sandy or muddy road as to provide for at least fairly comfortable travel throughout the year. Examples of the latter kind are by no means peculiar to the Southern States, but are to be found in nearly every section of the country. Table 7 shows the mileage of sand-clay roads in several representative States for 1909 and 1914, respectively, and illustrates how the popularity of this type of construction is increasing.

TABLE 7.—*Mileage of sand-clay roads in several representative States for 1909 and 1914.*

| States. | Sand-clay mileage. | | States. | Sand-clay mileage. | |
|------------------|--------------------|-------|----------------------|--------------------|-------|
| | 1909 | 1914 | | 1909 | 1914 |
| New Jersey | None. | 561 | Kansas | 202 | 758 |
| Virginia | 186 | 1,151 | North Carolina | 730 | 4,313 |
| Alabama | 1,107 | 1,916 | Texas | 2,254 | 3,684 |

The construction of sand-clay roads is essentially a matter of employing locally available materials to the best practicable advantage in producing an improved earth road surface. To do this involves an intelligent selection from the local materials and an adaptation of the construction method employed to the material selected. These two features of the work will be taken up separately in the order mentioned.

SELECTION OF MATERIALS.

The questions that ordinarily must be given principal consideration in the selection of materials for a sand-clay road surface are: (1) Is the soil composing the roadbed such that, if local sand or clay were admixed with it in proper proportion, a durable road surface can be produced? (2) Is topsoil of a suitable character available for use as a surfacing material? (3) Can a sufficient quantity of natural sand-clay subsoil for surfacing the road be obtained conveniently? (4) Can the two constituent materials be obtained separately and mixed in place on the road? (5) If a variety of materials are available, what selection or combination would give the best results and prove most economical in the long run? In deciding these questions, there are three ways in which the judgment may be assisted materially. These are, in the order of their importance, by means of service comparisons, field examinations, and laboratory tests. The questions and the customary manner of deciding them will be discussed briefly in the following paragraphs.

THE SOIL OF THE ROADBED.

In order to determine whether the soil of a given roadbed may be incorporated advantageously in a sand-clay road surface, it is necessary, of course, to consider the quality of the other local materials available for mixing with it, since the fitness of the roadbed soil for use in the surface necessarily must be limited by the quality of the other constituent material. In general, there are two conditions where the soil of the roadbed may be used advantageously in constructing the surface. One is where the roadbed is very sandy and plastic clay is more readily available for use in the surface than

a natural mixed sand-clay. The other is where the roadbed consists of a good quality of plastic clay and sand is available for the surface. In either case the appearance of the roadbed material may sometimes be very misleading under certain weather conditions, and before deciding whether it is suitable for use in the surface its behavior should be observed for all weather conditions to which the surface will be subjected.

For example, an earth road which appears very sandy in dry weather in reality may be composed of soil that will be converted into mud by even a very moderate rain. This is particularly true of soils that contain a high percentage of either very fine sand or silt. Where the roadbed is composed of such soil, no part of it should be incorporated in a sand-clay surface. The sand contained in a sand-clay surface is supposed to supply stability to the surface in wet seasons, and the roadbed material, to be adapted for this purpose, must be composed of sandy soil that will increase in stability with an increase in moisture content, and will not become muddy under any circumstances.

On the other hand, a roadbed that in wet seasons appears to be composed of clay suitable for use in a sand-clay surface may crumble into fine dust on drying out under even very light traffic. While a road surface constructed by mixing sand with soil of this kind might be a considerable improvement over the old earth road in both wet and dry weather, it would be very much inferior to a surface constructed by mixing together a good quality of nonslaking clay and sand.

TOPSOIL.

In the Piedmont and upper Coastal Plain regions of the South Atlantic States it happens often that the soil over limited areas of land is of such quality that a road surface made of it will possess all the desirable characteristics of a well-constructed sand-clay surface. A rather large mileage of roads has already been surfaced with soil of this kind and much of it is giving excellent satisfaction. Such roads are known locally as "topsoil roads."

The best topsoil for road surfacing usually is found in fields which have been under cultivation for a number of years. The probable reason for this is not only that cultivation produces a more intimate mixture of the soil constituents, but that the repeated aeration tends to improve the stability of the soil by causing the oxidation of certain component minerals. Also, where the original soil contains a too high percentage of clay, cultivation may have improved its quality by increasing the rate at which clay is leached out. Since cultivation ordinarily extends to a depth of only a few inches below the ground surface, the layer of soil suited for use in road surfacing is, in most

cases, very thin. The usual variation in the depth of this layer is from 4 to 12 inches. A suitable quality of topsoil is produced sometimes by agencies other than cultivation, when the depth may be considerably greater than 12 inches.

The safest guide in identifying topsoil that will make a satisfactory road surface is the service test, and, fortunately, it is nearly always possible to make this test by simply observing the condition of a section of road already constructed of the soil in question. The best method to follow in making a selection is to pick out such sections of earth road in the vicinity of the one to be surfaced as remain continuously in good condition. Then, if practicable, obtain the soil intended for the new road from the fields adjacent to the best sections of this good earth road. Otherwise employ specimens of the soil from these fields to compare with other available soils and base the selection on such comparisons. When comparisons are not conclusive the various kinds of available soil should be tried out on a small scale before any considerable area of topsoil surface is constructed, because there is at present no other reliable method for comparing the relative excellence of different topsoils and it is very easy to be misled into a wrong selection by incomplete laboratory tests.

The following list of characteristics usually belonging to topsoil of a satisfactory quality at least may prove helpful in selecting soils upon which to make the service test referred to above:

1. Some of the best topsoils so far discovered are of granitic origin; that is, the soil has been formed by the decomposition of granite.

2. Good topsoil usually has a very "gritty" texture, and when rubbed between the fingers this characteristic should seem more pronounced than any other.

3. Samples of soil taken from a number of first-class topsoil roads and subjected to mechanical analysis have shown an average sand content of from 50 to 75 per cent and an average clay content of from 25 to 50 per cent. But it appears that satisfactory results have been obtained most frequently where the sand content ranged between 65 and 70 per cent and the clay content between 30 and 35 per cent.

4. The color of good topsoil is more frequently gray than otherwise, but color is by no means an index to quality. Several cases have been reported where excellent results were obtained with a soil of dull-red color, while, again, a dark-brown soil has proved entirely satisfactory. Usually the color of the soil gradually becomes lighter after it is placed on the road, and some of the best gray soils have become almost white after a few years' service.

5. The soils designated ordinarily by farmers as "gray grit," "bright tobacco soil," "upland soil," and "rotten granite" have been found very frequently to possess the proper characteristics for

a good quality of topsoil. These names have considerable significance in some localities, but may mean practically nothing in others.

CLAY AND SAND.

Nearly all clays, as they occur in nature, contain more or less sand. Those in which the percentage of sand is sufficiently high to give the material a character decidedly intermediate between sand and clay are called natural sand-clay. Ordinarily, at least 40 per cent of sand is required to produce this intermediate character in a pronounced degree, and from 60 to 70 per cent usually is required to produce a first-class sand-clay surfacing material, though these percentages depend to a considerable extent on the respective qualities of the two constituent materials.

In general, the quality of clay is much more uncertain than that of sand and usually it is very difficult to determine in advance just what results may be expected from the use of a given clay in a sand-clay surface, except by means of a service test. But some time is required to make the service test, and, where none of the clay proposed for use occurs in an existing road surface, it may be very desirable to test the available material according to some quick method, so as to exclude from the service tests all clays which would not be likely to prove satisfactory. Some of the simplest methods for determining the probable wearing qualities of clay, or of a natural sand-clay mixture, by means of field inspection and laboratory tests are described below.

(1) To determine the proportion of sand present in clay, collect a representative sample of the clay and dry it thoroughly. After weighing the dry sample, place it in a vessel several times larger than the sample and wash out the clay content by filling the vessel repeatedly with water, agitating the clay and pouring off the muddy water. When all the clay has been washed out, dry the sand and weigh it. Then the proportion may be computed from the original weight and the weight of the sand. If the material tested happens to be of good quality of sand-clay, the weight of the sand will be about two-thirds that of the original sample.

(2) To compare the slaking qualities of two or more samples of clays, make up each sample into several balls of the same weight, dry out the balls thoroughly, and place them in water so that they will be covered entirely. The balls which hold their shape longest after being placed in the water have the highest resistance to slaking, and the clay which they represent usually is to be preferred for use in the road surface. If this test is to be at all conclusive, however, the different samples should contain about the same percentage of sand, and if there is much doubt about the sand content, it should be

determined for each sample prior to the time of making the slaking test, so that the percentage may be corrected by adding sand or clay. This test may be employed also to compare the slaking qualities of the same clay when mixed with different percentages of sand, and when so employed may afford a valuable guide in fixing the proper proportions for an artificial sand-clay mixture. In making the test several balls should be made and tested from each kind of clay, so as to afford check results. Also, in all the tests care must be exercised to keep the different samples from becoming confused after the balls are placed in the water. To do this, identifying marks may be placed upon the balls, or the balls from each sample may be placed in a different part of the containing vessel.

(3) The amount which clay shrinks on drying out also may be a measure of its fitness for use in a sand-clay surface. The shrinkage may be tested by observing the behavior of the clay balls while they are being dried out, when those which shrink most will develop most cracks. Other things being equal, the sand-clay mixture showing the smallest shrinkage is best suited for use in a road surface.

(4) Valuable comparative information regarding different available clays or sand-clay mixtures may be gained sometimes by simply observing exposed surfaces, where the materials outcrop, under different weather conditions. The best clays will be capable of standing on relatively steep slopes and will develop fewer surface cracks upon drying out after a wet season. They also will be little affected by frost and will appear dense and firm in dry weather.

(5) To test the suitability of sand for use in a sand-clay surface, place a sample of the sand in a vessel containing water and agitate the water until the sand is thoroughly in suspension. Then, after the sand has been allowed a few moments to settle, pour off the water slowly. If of good quality, the sand will not be carried out with the water but will remain in the vessel until practically all of the water has been drained off. Sand containing a large percentage of mica or other light mineral matter will not meet this test and is not generally suitable for use.

(6) The methods described above for testing sand-clay materials are based on the assumption that the selection must be restricted to materials locally available and are intended simply to aid in comparing the relative merits of such materials. But these methods can, of course, be adapted to more exact laboratory practice if so desired.¹

¹ A rather detailed plan for laboratory procedure, which has been followed to some extent in connection with the sand-clay roads of Georgia, is described by John C. Koch in the "Transactions of the American Society of Civil Engineers," Vol. LXXVII, December, 1914, p. 1454.

CONSTRUCTION METHODS.

The proper method to employ in constructing a sand-clay road surface depends on the conditions to be met. In general, there are four distinct sets of conditions, all of which may occur in the same locality, or even on different sections of the same road. These are:

Case 1, where the original roadbed is sandy and it is desired to construct the surface by admixing clay;

Case 2, where the original roadbed is composed of clay and it is desired to construct the surface by admixing sand;

Case 3, where it is desired to construct the surface of topsoil or other natural sand-clay mixture without admixing any of the roadbed material;

Case 4, where it is desired to supply the clay and sand separately and mix the two materials together in place to form the surface.

Before discussing the different cases separately, the general ends which all of the construction methods should aim to attain will be summarized briefly.

(1) The questions of location, design, drainage, grading, etc., are, if anything, more important in the case of sand-clay roads than in the case of earth roads. These questions have all been discussed in another part of this bulletin.

(2) The amount of clay contained in a finished sand-clay road surface should be only slightly more than sufficient to fill the voids in the sand. Ordinarily about one part of clay to two parts of sand gives satisfactory results, though the proper proportion for any particular case can be determined best by experiment.

(3) For average country-road traffic and a stable roadbed, the depth of a sand-clay surface should be about 8 inches after it is compacted. If clean sand and pure clay were used to make the mixture, the respective depths of the sand layer and the clay layer required would be approximately 8 inches and 4 inches, measured loose. It is customary to decrease the surface thickness from center to sides, with a feather edge extending out over the shoulders, but this practice makes it necessary for most of the traffic to use the center of the road, and heavy vehicles using the edge of the surface are liable to break through the surfacing material.

(4) In constructing a sand-clay surface, the two constituent materials should be thoroughly and intimately mixed together in all cases. In making artificial mixtures, therefore, much plowing and harrowing are required.

(5) No matter what method is followed in constructing a sand-clay surface, traffic usually must be depended upon to puddle and compact the surfacing material, and the road never should be con-

sidered complete until after it has been subjected to traffic for a considerable period. During this period the surface should be kept in shape by repeated dragging, and if necessary additional sand or clay should be supplied at points which show weakness owing to these materials not having been mixed in proper proportions.

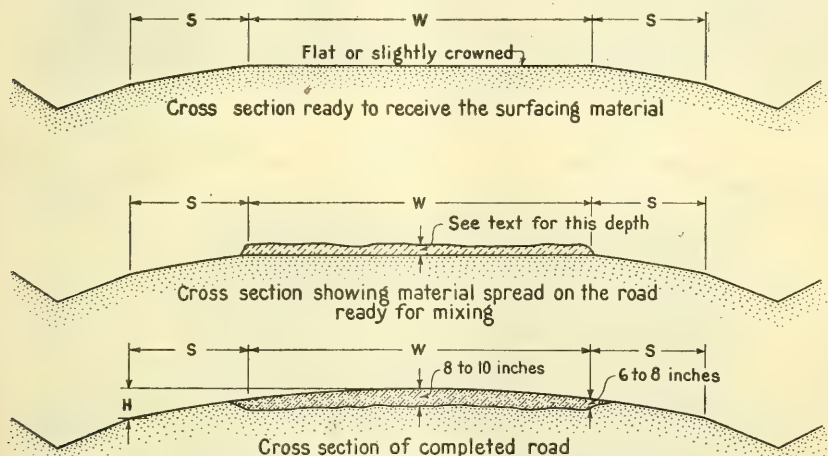
Other features of the construction can best be described separately for each of the four sets of conditions mentioned above.

Case 1.—To construct a sand-clay surface by admixing clay with sand from the roadbed, first grade the roadbed in the manner already described for earth-road construction, but keep the crown flat on the portion to be surfaced. Then spread clay over that part of the roadway which the surface is to cover, to such depth that, when it is mixed with the sand of the roadbed, a surface about 8 inches thick, after compacting, will be obtained. The loose depth of clay necessary to secure a finished surface 8 inches thick usually will vary from 4 inches to 6 inches, according to the amount of sand the clay contains. After the clay has been spread, plow up sand from beneath in sufficient quantity to make the net proportion of sand to clay about 2 to 1. Ordinarily the plow furrows should extend down into the sand from 4 to 6 inches, depending on the compactness of the roadbed and the amount of sand originally present in the clay. But it is better to have too little than too much sand, because it is easier to add sand from the roadbed than to haul additional clay. Next harrow the surface with a disk harrow. Repeat the operations of plowing and harrowing until the sand and clay are mixed thoroughly and uniformly. Then shape up the surface with a grading machine or road drag and permit traffic upon it. After the first soaking rain, plow and harrow the surface again until the surfacing material practically becomes mud, after which shape up the surface and keep it in shape by repeated dragging until it has dried out and is thoroughly compacted. Watch the road carefully for several months after it is first constructed, to correct deficiencies of sand or clay and to keep the surface in shape. The cross sections shown in figure 20 illustrate the principal steps involved in constructing a sand-clay road surface according to the method just described, as well as the one described in the following paragraph.

Case 2.—To construct a sand-clay road surface by admixing sand with clay from the roadbed, the process is exactly similar to that described for Case 1, except that sand is spread over the graded roadbed and clay is plowed up from beneath to mix with it. The depth to which the sand should be spread for an 8-inch finished surface usually varies from 4 inches to 8 inches according to the amount of sand contained originally in the clay of the roadbed. The depth to which the plow furrows should extend down into the clay usually varies from about 3 inches to about 5 inches, and depends on the sand

content of the clay and the compactness of the roadbed. It should be borne in mind that, in this case, it is better to have a surplus of sand than a surplus of clay in the surface, because the former is more easily corrected.

Case 3.—Figure 21 illustrates the two principal steps involved in constructing a sand-clay surface with topsoil or other natural sand-clay mixture. The roadbed should be graded in the usual way, except that the portion to be surfaced should be trenched out with the grading machine to receive the surfacing material. The surfacing material should be spread to such a depth that it will be at least 8



TYPICAL CROSS SECTIONS SHOWING METHOD OF CONSTRUCTING SAND-CLAY ROAD BY MIXING SAND OR CLAY WITH THE ROAD BED MATERIAL.

"W" should be at least 12 feet for single track road, and "S" generally not less than 5 feet, for double track "W" should be not less than 14 feet, and "S" not less than 3 feet. "H", crown, varies from $\frac{1}{2}$ " to the foot for level grade, to 1" to the foot for a grade of 5%.

FIG. 20.

inches thick at the center when compacted. After this is done permit traffic upon the road and keep the surface in shape with a road drag while it is being compacted. Where surfacing material may be obtained cheaply trenching is frequently omitted altogether, and the artificial surface is extended out over the shoulders.

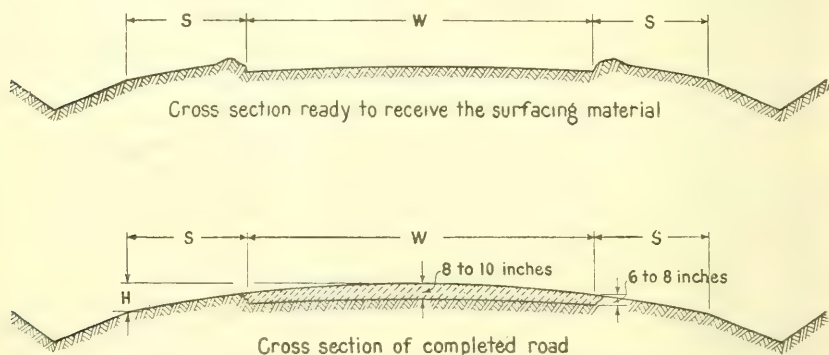
Case 4.—Where it is necessary to bring the sand and clay on the road separately and mix them in place, the method employed should be a combination of the methods already described. That is, a trench should be formed with the grading machine to receive the bottom layer of material, which may be either the sand or the clay, and the top layer should then be spread and the mixing done as described in Case 1 or Case 2. The depths of the respective layers should be such as to secure a completed surface at least 8 inches thick, and the proportions should be fixed in the manner already described in discussing the other cases. Where the roadbed material

consists of clay which is not considered suitable for use in the surface, it is well to spread the sand layer first and to make its depth more than is sufficient for use in the surface. The surplus sand which remains under the completed surface then will serve to improve the drainage of the road.

Plate IV, figures 1, 2, and 3, illustrates the several principal features involved in the construction of a sand-clay road and supplements the information given in the text.

COST OF SAND-CLAY ROADS.

From the foregoing discussion of construction methods, it is apparent that the conditions under which sand-clay roads are con-



TYPICAL CROSS SECTIONS SHOWING METHOD OF CONSTRUCTING A SAND-CLAY ROAD, USING TOPSOIL OR OTHER NATURAL MIXTURE.

"W" should be at least 10 feet for single track road and "S" generally not less than 5 feet, for double track, "W" should be not less than 14 feet and "S" not less than 3 feet.

"H", crown, varies from $\frac{1}{2}$ " to the foot for level grade, to 1" to the foot for a grade of 5%

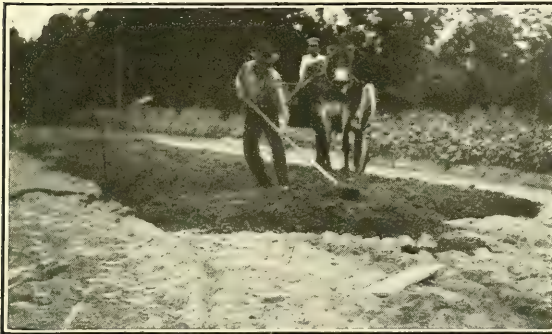
FIG. 21.

structed vary over a wide range, and that any general statements regarding costs may be very misleading when applied to a particular case. In general, for a cost estimate to be at all reliable it should be arrived at by considering the following items: (1) grading and preparing the subgrade, (2) excavating and loading surfacing material, (3) hauling surfacing material, (4) mixing and shaping surfacing material.

Table 8 shows the cost of these items for several different sand-clay roads which have been constructed under the supervision of the Office of Public Roads and Rural Engineering and may be of some assistance in preparing estimates of probable cost for similar projects. As a matter of general information it may be stated that in the Southern States the cost of constructing 16-foot sand-clay



FIG. 1.—SAND ROAD BEFORE IMPROVEMENT.



OPRE2028

FIG. 2.—CONSTRUCTING SAND-CLAY ROAD.



OPRE4866

FIG. 3.—SAND-CLAY ROAD; FINISHED AND IN SERVICE.



surfaces, exclusive of grading, usually has ranged between \$500 and \$1,500 a mile.

TABLE 8.—*Cost of sand-clay roads, exclusive of grading and materials.*

| Items. | Project number. | | | | | | | |
|--|--------------------------|-----------------------|------------------------|------------------------------|-----------------------|------------------------|------------------------|-----------------|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| | Brook-
ville,
Fla. | Mos-
cow,
Miss. | Pear-
sall,
Tex. | San
An-
tonio,
Tex. | Gay
Head,
Mass. | Jack-
son,
N. C. | Tar-
boro,
N. C. | Sayre,
Okla. |
| Length surfaced in miles..... | 0.45 | 0.78 | 0.79 | 1.00 | 2.19 | 0.45 | 2.50 | 0.75 |
| Width of graded road in feet: | | | | | | | | |
| Cuts..... | 28 | 30 | 26 | 40 | 22 | 30 | 22 | 28 |
| Fills..... | 20 | 30 | 26 | 26 | 22 | 30 | 22 | 28 |
| Width surfacing (feet)..... | 16 | 17 | 15 | 16 | 16 | 14 | 18 | 14 |
| Sand mixture: | | | | | | | | |
| Sand (cubic yards)..... | 660 | 1,524 | ----- | ----- | 1,700 | ----- | ----- | ----- |
| Distance hauled in miles..... | 0.75 | 1.5 | ----- | ----- | 0.125 | 1.00 | ----- | ----- |
| Depth applied in inches..... | 3 | ----- | ----- | ----- | 6 | ----- | ----- | ----- |
| Clay mixture: | | | | | | | | |
| Clay (cubic yards)..... | 830 | ----- | 1,556 | 1,825 | 2,300 | 890 | 2,815 | 1,383 |
| Distance hauled in miles..... | 0.50 | ----- | 0.19 | 0.057 | 0.10 | 1.00 | ----- | 1.42 |
| Depth applied in inches..... | 7 | ----- | 8 | 7 | 6 | ----- | 6 | 8 |
| Scale of wages per hour: | | | | | | | | |
| Laborers..... | \$0.175 | \$0.10 | \$0.12 | \$0.15 | \$0.20 | \$0.12½ | \$0.08 | \$0.16 |
| Teams..... | .50 | .25 | .30 | .34½ | .50 | .35 | .24 | .30 |
| Cost: | | | | | | | | |
| Subgrade, per square yard..... | .031 | .003 | .0064 | .0088 | ----- | .002 | .0018 | .0096 |
| Stripping for surfacing material,
per cubic yard..... | ----- | ----- | .091 | .072 | .010 | .029 | .005 | .134 |
| Hauling sand, per cubic yard..... | .425 | .49 | ----- | ----- | .223 | .84 | ----- | ----- |
| Hauling clay, per cubic yard..... | .374 | ----- | .914 | .286 | .344 | ----- | .255 | .567 |
| Spreading material, per cubic yard..... | .019 | .007 | .032 | ----- | .003 | .077 | .0178 | .072 |
| Mixing sand and clay, per square
yard..... | .0035 | .006 | .0017 | .0069 | .010 | ----- | .0024 | .007 |
| Final shaping, per square yard..... | .0035 | ----- | .0005 | .0015 | .004 | .002 | .0022 | ----- |
| General expense, per square yard..... | .0157 | ----- | .003 | ----- | .006 | .003 | .0007 | ----- |
| Total cost, per square yard..... | .198 | .105 | .121 | .089 | .082 | .233 | .036 | .187 |

GRAVEL ROADS.¹

Roads that are artificially surfaced with gravel, as defined on page 18, or with earthy material in the composition of which gravel predominates, are called gravel roads. This designation covers a variation in type which ranges from roads surfaced with a natural sand-clay mixture containing a considerable percentage of gravel to those having so-called "gravel macadam" surfaces, composed almost wholly of pebbles and constructed in practically the same manner as first-class macadam roads. Gravel roads constitute about one-third the total mileage of surfaced roads in the United States and are confined to no especial section of the country.

In the following discussion of gravel roads it is convenient to consider the subject under the two general heads, "Selection of Gravel" and "Construction Methods."

¹ It is desired to acknowledge the assistance of W. H. Rhodes, U. S. highway engineer, in preparing this discussion, and of J. T. Voshell, J. D. Fauntleroy, J. A. Whitaker, and James C. Wonders, U. S. district engineers, in reading and revising the text.

SELECTION OF GRAVEL.

Ordinarily the selection of gravel for use in road surfacing must be confined to local materials which are or can be made suitable for that purpose. Because of high freight costs it seldom happens that road gravel of even the very best quality is transported by rail a greater distance than about 100 miles from the source of supply, and in the vast majority of cases it is hauled directly from pit to road in wagons. Since the quality of gravel varies to a considerable extent, sometimes in different parts of the same pit, it is essential that local road officials, who frequently are charged with the selection of such material, should have some knowledge of the relation between the physical characteristics of gravel and its wearing qualities when placed in a road surface. While such knowledge can best be gained by actual experience with different kinds of gravel, there are certain general requirements which may be stated for the guidance of the inexperienced. For example, the following excerpt from Bulletin No. 2 of the Michigan State highway department presents in very concise form the characteristics which gravel for road surfacing should possess, in the judgment of the State highway commissioner, in order to meet the Michigan conditions.

Next to proper drainage, the most important thing in building gravel roads is to secure a good quality of gravel. Authorities have differed as to the requirements of suitable road gravels, most of them, in my opinion, placing too much stress on the immediate packing qualities. Indeed, the average township commissioner and farmers generally have become so imbued with the idea that it is necessary to use a gravel that will pack quickly that they have almost lost sight of the fact that the only thing which makes a gravel road better than an earth road is the pebbles, real stones, that it contains and is dependent upon to bear up traffic and resist wear.

The most common material sought after for the binder in gravel roads is clay. But, considering all kinds of weather, it is probably the poorest cementing material we have. If present, much in excess of 10 per cent of the mass, it will make mud whenever there is a prolonged wet spell, and especially when frost is coming out of the ground in the spring. Ideal clay gravels contain only enough clay to coat the pebbles, with no free lumps. Such gravels are excellent for the first layer on sandy soils, but sand gravels are much better for the first layer on clay and loamy soils.

Gravels that come from the pit with the pebbles cemented together, even though they contain no clay, will recement in the road and become harder than they were in the pit. Tests of specimens of this kind always show that there is much lime present and usually some iron, both of which are excellent cementing materials. Briefly, the experience of the State highway department warrants the statement that there are few, if any, bank gravels in Michigan that do not contain enough limestone and other soft pebbles which grind up under traffic to furnish sufficient binder to cause them to consolidate in a few months' time, if separated from the surplus sand and earth, and properly treated after applying to the road.

In accordance with these suggestions, gravels are considered valuable for road purposes in the following order:

(1) Almost in direct proportion to the percentage of pebbles constituting the mass.

(2) In direct proportion to the value as road metal of the rock fragments constituting the pebbles.

(3) In direct proportion to the value as a cementing material under all conditions of weather, of the finer particles of earthy matter constituting the filler or binder.

Since Michigan is one of the leading States in mileage of roads surfaced with gravel, the experience of the State highway department, as stated in the paragraphs quoted above, should be of considerable value to road officials in other localities, especially where the gravel deposits are principally of glacial origin, as is the case in Michigan. But in many sections of the United States the gravel deposits contain practically no fragments of limestone or other soft rock which might pound up under traffic and serve as a binder to hold the larger particles together, and under such conditions clay or a sand-clay mixture usually must be depended upon to perform this office.

In general, the physical characteristics of gravel which determine its suitability for use in surfacing a road are:

(1) The durability of the pebbles or rock fragments, (2) the quality of the binder, (3) the grading of the pebbles, and (4) the proportion in which the binder material is present. While the influence each of these factors should exert in fixing the selection of gravel for a particular road depends upon local conditions and necessarily is a question for individual judgment to decide, nevertheless a few points in connection with each factor that may aid materially in reaching a decision will be summarized in the following paragraphs.

DURABILITY OF PEBBLES.

The principal qualities which determine the durability of pebbles or stone of any kind when placed in a road surface are hardness, toughness, and resistance to wear. The extent to which pebbles possess these qualities depends very largely on the character of the parent stone from which they were originally produced and accordingly varies over a wide range. Since nearly all gravel deposits contain pebbles which have been formed from many different kinds of stone, it has not been considered practicable to apply the ordinary laboratory tests¹ for determining hardness, toughness, and per cent of wear to gravel, and the matter of comparing these qualities, as possessed by the pebbles from different gravel deposits, usually depends on visual inspection. Not infrequently a very casual inspection will reveal which deposit, among a great number, contains

¹ U. S. Department of Agriculture Bulletin No. 347, "Methods for the Determination of the Physical Properties of Road-Building Rock."

the largest percentage of hard durable pebbles. There are comparatively few cases where this point can not be determined with sufficient accuracy by sorting out the pebbles contained in representative samples from the different deposits, testing the various kinds with a hand hammer, and determining the relative proportions in which the more durable materials are present in the sample by means of a weighing device.

Ordinarily the most durable pebbles which occur in gravel deposits are those composed of either quartzite or chert, though many deposits contain fragments of limestone or trap rock, either of which may make an excellent road-surfacing material. For example, the so-called "blue gravel" which occurs in certain sections of the country usually is composed largely of trap-rock fragments and generally ranks high as a road material. While limestone pebbles are less resistant to wear than those of trap rock, they possess the advantage of a relatively high cementing value and their presence in gravel may aid greatly in securing a well-bonded surface without an excess of clay.

The pebbles which are least durable but very prevalent in gravel deposits are those composed of sandstone. As a rule, such pebbles are lacking greatly in toughness and will shatter under traffic. Gravel deposits also may contain a high percentage of partially disintegrated pebbles which are even less durable than sandstone. "Bastard granite" is a common example of partially disintegrated rock, and not infrequently it happens that gravel deposits contain a high percentage of this material. Partially disintegrated chert is found occasionally in gravels, but as such material possesses a relatively high cementing value, its presence in small proportion may be an advantage rather than a detriment to gravel deposits.

THE BINDER.

No matter how durable may be the pebbles contained in a given gravel deposit, they can not be used successfully in a road surface unless they can be well bonded together so as to present a combined resistance to the disturbing action of traffic. To accomplish this bond requires that the gravel contain some cementing or binding agent such as iron oxide, carbonate of lime, or clay. As already explained, certain pebbles, such as those composed of limestone, possess the property of becoming firmly bonded together by virtue of their own cementing value.

The principal cementing agent, or binder, present in most gravel deposits is clay, and in case of deposits which do not carry sufficient binder, clay usually is the material added to correct the deficiency.

While there are many exceptions to this rule, it is sufficiently general to warrant treating as special cases those deposits in which the binder is not clay.

The suitability of clay for use as a binder for a gravel road surface depends on exactly the same characteristics as its suitability for use in sand-clay construction (see pp. 39 et seq.). That is, a quality of clay which could be used satisfactorily in a sand-clay surface also should make a satisfactory binder for a gravel surface, provided it is used in proper proportion and is properly mixed with sand.

Where the binder consists of some material other than clay its efficiency usually may be tested by observing an exposed bank of the gravel deposit. If the binder is of satisfactory quality, the gravel should be capable of standing on a practically vertical slope and nearly always will contain many lumps composed of numerous pebbles cemented together with the binder. These characteristics are especially noticeable in the case of gravel deposits in which the binder consists essentially of iron oxide, as in some deposits found in New Jersey, Mississippi, and the lake basins of the West.

GRADING AND PROPORTIONS.

For gravel to make a satisfactory road surface, the stone particles should be graded in size so that the amount of binder required will be reduced to a minimum. The reason for this is that the binder usually is much less resistant to wear than the stone particles, and therefore it is desirable that the latter form as large a part of the wearing surface as is practicable. Most gravel deposits as they occur in nature satisfy this requirement in so far as grading of the pebbles is concerned, but they nearly always contain pebbles of a size larger than it is desirable to incorporate in a road surface. Natural deposits also not infrequently contain too large a proportion of sand or clay to produce satisfactory results. It is desirable, therefore, that specifications covering gravel for use in road construction should limit the proportions in which the fine and coarse materials shall be present and a maximum limiting size for the pebbles, as well as definite requirements regarding the quality of the pebbles and of the binder.

Table 9 shows the results of a number of tests made by the Office of Public Roads and Rural Engineering on gravel obtained from various parts of the country, with comments as to the suitability of the different samples for use in road surfacing. The comments are based on observation of existing gravel roads constructed of similar materials and are believed to be well grounded.

| Bennington
County, Vt. | 9.719.933.451.371.780.484.7 | 15.386.091.194.896.197.097.797.998.8 | 1.2 | Fair..... | Good..... | Fair..... | Sample contains too large a proportion of material over 1 inch, and does not contain sufficient binding material. |
|-----------------------------|------------------------------|--------------------------------------|------|-------------|------------|------------|---|
| Do..... | ..... | ..... | 1.4 | Low..... | Fair..... | Fair..... | Does not contain sufficient binding material. |
| Fond du Lac
County, Wis. | 12.618.926.237.448.062.472.5 | 27.575.583.888.090.092.094.094.594.6 | 5.4 | Very good. | Good..... | Good..... | Should prove satisfactory under light traffic. |
| Yazoo County,
Miss. | 7.5 8.717.933.845.056.763.3 | 36.765.067.870.473.782.486.086.286.4 | 13.6 | Fair..... | Excellent. | Good..... | This material should prove satisfactory. |
| Jackson County,
Miss. | | 89.211.817.936.061.086.091.892.093.0 | 7.0 | No test.... | Excellent. | Excellent. | The quantity of sand should be reduced by about 30 per cent. |
| Franklin County,
Mo. | | 46.856.465.573.579.283.687.288.190.2 | 9.8 | Good..... | Excellent. | Excellent. | The proportion of sand is too high and the grading is not good. |
| Do..... | ..... | 54.051.568.381.489.494.096.296.697.8 | 2.2 | Good..... | Excellent. | Excellent. | This material should prove satisfactory. |
| Yellowstone
County Mont. | 24.032.341.655.369.377.379.2 | 20.879.679.981.284.092.098.198.899.9 | 0.1 | Good..... | Excellent. | Excellent. | Do. |
| Denver County,
Colo. | 29.436.143.950.058.566.872.4 | 27.674.080.684.586.789.191.492.093.3 | 6.7 | Excellent. | Excellent. | Excellent. | Do. |
| Pickens County,
Ala. | | 42.759.368.576.579.884.190.591.292.6 | 7.4 | Fair..... | Very good. | Good..... | Probably satisfactory, although the proportion of sand is high. |
| Comal County,
Tex. | 15.821.126.834.545.462.172.8 | 27.275.882.084.986.387.989.289.590.5 | 9.5 | Good..... | Excellent. | Very good. | This material should prove satisfactory. |

In general, it has been found that satisfactory gravel will conform to the following limits as to percentages of fine and coarse material:

- (1) Material retained on a $\frac{1}{4}$ -inch sieve, 55 to 75 per cent.
- (2) Material retained on a $\frac{3}{4}$ -inch sieve, not less than 15 per cent.
- (3) Material (clay) passing a 200-mesh sieve for the surface course, 8 to 15 per cent.
- (4) Material (clay) passing a 200-mesh sieve for the foundation course, 10 to 15 per cent.

The sand content should be at least twice as great as the clay content; and the sand and clay, when thoroughly mixed, should be sufficient to fill the voids between the larger gravel particles. The percentages given above usually will conform to this requirement. The maximum limiting size for the pebbles ordinarily should be from $2\frac{1}{2}$ to 3 inches, because where larger particles are permitted in the surface the rate of wear is made unequal, and it is more difficult to maintain a satisfactory bond between the different particles.

A satisfactory mechanical analysis of a gravel sample along the lines indicated above frequently may be made in the field by first separating the coarse material from the fine by means of a $\frac{1}{4}$ -inch mesh screen and then washing the clay out of the fine material, as described in the discussion of sand-clay roads. Both the coarse and fine materials obtained from the sample may be further separated into different sizes by means of suitable screens if, for any reason, this is desirable in making the test.

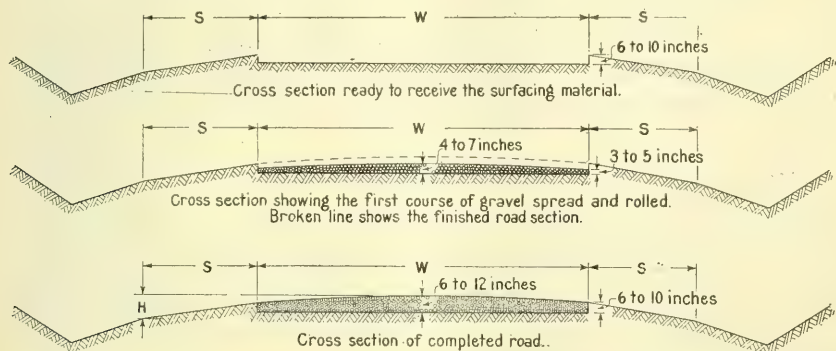
It happens very often that a mechanical analysis will indicate the necessity of screening the natural gravel to remove a portion of either the fine or coarse material so as to keep the proportions within the limits mentioned above. It is also necessary sometimes to wash the gravel in order to remove excessive clay, but this process is expensive, and it is generally practicable to secure the desired results by screening. When the analysis shows the desirability of adding clay or sand to the gravel, this should be done as the surface is constructed by spreading a uniform layer of the needed material over each course of gravel and mixing it thoroughly into the mass by harrowing.

CONSTRUCTION METHODS.

Figure 22 shows a typical cross section for a gravel-road surface and indicates the customary steps involved in the construction of such a surface. The limiting thicknesses shown on this cross section are by no means followed universally, but are believed to represent the best current practice. The minimum thickness shown is supposed to be employed where the traffic is light and the subgrade is uniformly stable, while the maximum thickness is adapted for opposite conditions. Perhaps the most usual compacted thickness of surface

is 8 inches at the center and 6 inches at the edges. The difference in thickness between the edges and the center is effected by making the crown of the subgrade flatter than that of the surface.

The construction of a gravel road usually is divided into two entirely distinct classes of work. The work of grading and preparing the subgrade falls into one class, and that of hauling, spreading, and compacting the gravel into the other. The first class of work has been discussed at considerable length in connection with earth and sand-clay roads, but since it is desired to emphasize certain features of subgrade preparation that are of increased importance



TYPICAL CROSS SECTIONS SHOWING METHOD OF CONSTRUCTING A GRAVEL ROAD

"W" should be at least 10 feet for single track roadway and "S" generally not less than 5 feet; for double track, "W" should be not less than 14 feet and "S" not less than 3 feet.

"H", crown, varies from $\frac{1}{2}$ inch per foot for level grade, to 1 inch per foot for a grade of 5%.

FIG. 22.

in connection with gravel road construction, both classes of work will be considered in the following discussion.

PREPARATION OF THE SUBGRADE.

In grading the roadbed and preparing the subgrade for a gravel surface, all of the precautions previously noted as applying to similar features of earth and sand-clay road construction should, of course, be observed. It should be borne in mind also that the more expensive a road surface, the greater should be the care exercised to prevent it from being damaged through settlement or upheaval of the subgrade, and the greater should be the accuracy with which the subgrade is constructed, so that no unnecessary surfacing material may be required to correct irregularities in grade and cross section. No matter what the soil conditions may be, the subgrade for a gravel road surface, when completed, should conform closely in grade and cross section to the requirements of the plans and should present

an even, uniform appearance. Also, it should be as firm and unyielding as the conditions will permit.

Some of the most important details requiring careful attention in preparing the subgrade, and which are perhaps most frequently overlooked, are (1) backfilling culvert trenches so as to prevent subsequent settlement, (2) exclusion of vegetable matter from fills, (3) provision for draining wet-weather springs which occur in the subgrade, and (4) the matter of thoroughly loosening and distributing the materials contained in old road crusts. These details are treated briefly in another part of this bulletin.

After the roadbed has been graded and drained properly, and the details mentioned above have received proper attention, the work of preparing the subgrade consists simply in forming a trench, as shown in figure 22, to receive the gravel surface. The trench may be formed largely with a grading machine, the operation of which is described on page 21, but the final shaping should be effected by means of picks and shovels and rolling. It is customary to provide grade stakes at intervals of about 50 feet, to serve as a guide for the pick and shovel work, and where extreme accuracy is desired cords may be stretched between the stakes to insure that the subgrade conforms to the required grade throughout. The rolling is done ordinarily with a power roller weighing about 10 tons.

In order that the subgrade may be well drained during the process of spreading and compacting the gravel it is frequently necessary to provide shoulder drains at comparatively short intervals. Such drains are constructed by opening small ditches through the shoulders and partially filling them with gravel. (See specification on page 66.)

THE GRAVEL SURFACE.

The principal precautions to observe in constructing a gravel road surface, after the subgrade is prepared, may be commented upon briefly as follows:

(1) The gravel should be delivered on the work in wagons or cars especially adapted for spreading each load uniformly over that part of the subgrade for which it is intended. Where loads are dumped all in one spot and spread later with shovels, as is done frequently, it is very difficult to secure uniform density of the surface crust by subsequent harrowing and rolling. The spots where the loads are dumped nearly always will be more densely compacted than the areas between, and, as a result, uneven settlement will develop soon.

(2) The gravel should be spread in two or more courses, and the thickness of the different courses should be approximately the same, except that the first course may be made somewhat thicker than the

succeeding courses, because, in general, a thicker layer of gravel may be compacted on the subgrade than when spread over a layer of gravel already compacted. It usually is impracticable to have the compacted thickness of any course greater than about 5 inches, and quite frequently 3 or 4 inches is as much as can be compacted satisfactorily at one time.

(3) After each course of gravel is spread it should be harrowed with a tooth harrow until the various sizes of particles and the binder or cementing material are distributed thoroughly through the mass. Then it should be compacted by rolling with a power roller weighing about 10 tons, or by means of traffic. Where a roller is employed the rolling should be continued until the particles of gravel are all well bonded together and the surface presents a smooth, uniform appearance. When completed, the surface of each course should be so firm and unyielding that it will not be disturbed in any way by subsequent traffic.

(4) Where it is necessary to add sand or clay to the gravel in order to fill the voids it should be done after each course is spread and before it is harrowed, except that with some kinds of gravel it may be permissible to add a limited amount of fine material to the surface of the top course after the harrowing is completed and the rolling is in progress.

(5) Where the binder consists of some material other than clay, it may be desirable to sprinkle each course with water while it is being rolled, and even where clay is used as a binder a small amount of sprinkling may be necessary in dry weather in order to secure a satisfactory bond. The sprinkling should be done uniformly and in such quantities as not to wash the fine material out from the gravel or to soften the subgrade.

(6) When the road surface is complete it should be uniform in grade and cross section. If depressions occur under the roller they should be corrected by adding gravel and continuing the rolling, and this should be kept up until no depressions or appreciable waves are produced by the roller in moving back and forth over the surface.

(7) After the road is opened to traffic, it should be watched very carefully for several months and all defects which develop should be corrected immediately. The work of maintaining the road until the surface no longer "picks up" or ravel under traffic should be considered an essential feature of the construction. When traffic is depended upon to compact the gravel, much dragging is necessary in order to secure a smooth, well-bonded surface. In fact, the cost of dragging, under such conditions, frequently may exceed the cost of securing a well-bonded surface by means of rolling.

Plate V, figures 1, 2, and 3, illustrates the different kinds of work involved in gravel-road construction.

The construction method described above is modified quite frequently by omitting the subgrade trench and the rolling. The practice followed in many localities is simply to grade up the roadbed and heap gravel along the central portion. Traffic is then depended upon to spread and compact the gravel and produce a uniform surface. While some of the roads constructed in this way are great improvements over the original earth roads they nearly always are crowned too much for comfortable driving, and seldom wear as well as when the more careful method of construction is followed. It is believed, therefore, that in the long run it pays to employ a trenched subgrade and to compact the surface by rolling, though a possible exception to the economy of a trenched subgrade may exist where good gravel may be obtained very cheap. In this case it may be cheaper to surface the entire roadway than to incur the additional expense of trenching and constructing earth shoulders.

COST OF GRAVEL ROADS.

In estimating the cost of a gravel road it is necessary to consider (1) the cost of grading and preparing the subgrade, (2) the purchase price of the gravel it is proposed to use, (3) the cost of delivering the gravel on the road, and (4) the cost of spreading and compacting the gravel.

The cost of grading has been discussed in connection with earth roads and need not be considered here. But it should be borne in mind that the cost of preparing the subgrade, after the rough grading is complete, depends to a very considerable extent upon the degree of care exercised in doing the latter work. The character of the soil composing the roadbed also may be an important factor in determining the cost of preparing the subgrade, especially if any considerable period of time elapses after the completion of the rough grading before the subgrade is prepared. Some soils remain loose indefinitely and are worked into proper shape easily, while others may become hard and compact in a very short time after being placed in a roadbed.

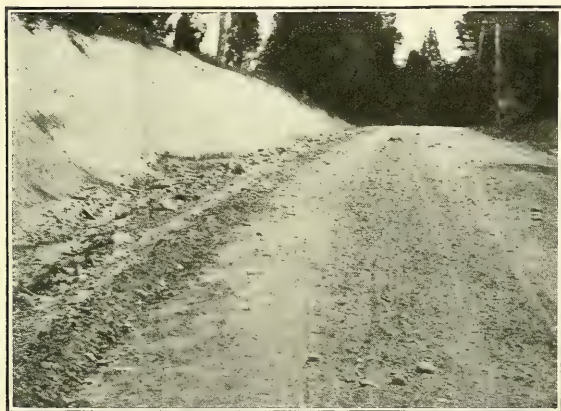
Where a road has been graded previously with moderate care and has not settled out of shape or been allowed to erode, and where the price of labor is about 20 cents per hour and of teams about 40 cents per hour, the cost of preparing a subgrade for a gravel road surface varies about as follows:

| | Cents
per square
yard. |
|--|------------------------------|
| Light loam soil | 1½ to 2 |
| Light clay soil, freshly graded..... | 2 to 4 |
| Stiff clay soil, freshly graded..... | 3 to 5 |
| Stiff clay soil, thoroughly compacted..... | 5 to 8 |



OPPRE13573

FIG. 1.—CONSTRUCTING A GRAVEL ROAD SURFACE IN TWO COURSES.



OPPRE11129

FIG. 2.—COMPLETED GRAVEL ROAD IN USE.



OPPRE12780

FIG. 3.—GRAVEL PIT IN ALEXANDRIA COUNTY, VA.



These costs include all necessary rolling for compacting the subgrade.

The two succeeding factors, purchase price of gravel and cost of delivering the gravel on the road, evidently are dependent to a very great extent on local conditions, and their influence on the cost of a given road can not be determined except by a study of those conditions. The following data are intended to serve only as an aid in making the necessary study.

(a) A cubic yard of loose gravel ordinarily weighs between 2,700 pounds and 3,300 pounds, the average weight being about 3,000 pounds.

(b) Loose gravel will shrink from 20 per cent to 30 per cent in volume when compacted in a road surface. In determining the loose volume of gravel required for a given project, it is customary to compute the compacted volume and add at least one-third.

(c) The average cost of loading pit gravel by hand into wagons is about 20 cents per cubic yard. Where the amount of work to be done is sufficient to warrant the installation of a steam shovel or the construction of a special scaffold so that wheeled scrapers may be used for loading, the cost of this work may be reduced, sometimes 50 per cent or more.

(d) The cost of screening gravel varies greatly according to the character of the pit-run material and the kind of screening equipment employed. Hand screening usually costs from 25 cents to 48 cents per cubic yard, while with a properly arranged mechanical screen the cost should not often exceed 15 to 20 cents per cubic yard.

(e) The cost of hauling depends on the equipment used and the condition of the road over which the hauling is done. With teams at 50 cents per hour and the roads such that 2 tons may be hauled at a load the average cost for hauling is about 25 cents per ton-mile, or $37\frac{1}{2}$ cents per cubicyard-mile.

The fourth factor to consider, cost of spreading and compacting the gravel, depends on the character of the gravel and of the equipment, as well as on the cost of labor. On five gravel-road projects recently completed under the supervision of the Office of Public Roads and Rural Engineering the cost of spreading the gravel ranged from about 3 cents to about 8 cents per cubic yard. The average cost was about $6\frac{1}{2}$ cents per cubic yard, and the average cost of labor was about 20 cents per hour. The wagons used in all cases were dumped directly upon the subgrade and were designed to spread the material to a considerable extent while it was being dumped.

The cost of rolling the gravel on the above five projects ranged from slightly less than $\frac{1}{2}$ cent per square yard of surface to about 1 cent per square yard, and the average cost was about 0.6 cent

per square yard. These costs include labor only, and if fuel for the roller and depreciation were considered, the average cost probably would approximate $1\frac{1}{2}$ cents per square yard.

ROAD MAINTENANCE.

METHODS OF MAINTENANCE.

As soon as a road is constructed, the action of traffic and the weather begin to destroy it, and to counterbalance the effects of these deteriorating influences it is necessary to institute some system of maintenance. There are two common ways of maintaining a road. One is to make periodic repairs or renewals after sections of the road have been practically destroyed; the other is to employ a system of continuous maintenance under which all injuries to the road are repaired as fast as they occur. For the types of roads which have been discussed the system of continuous maintenance is much more preferable from practically every standpoint, and that system alone will be discussed here.

THE ROAD DRAG.¹

The road drag is a simple and inexpensive device for maintaining certain types of roads which, when wet, become rutted under traffic but which become firm on drying out. It is useful also in producing a smooth and uniform surface on newly constructed roads of earth, earthy gravel, or any similar material. Figures 23 and 24 show typical designs for road drags made, respectively, of a split log and of sawed timber, and drags made in accordance with either design may be operated with two horses.

Properly used at the right time the drag performs four distinct functions: first, by moving at an angle with the traveled way, it tends to produce or preserve a crowned cross section; second, if used when the surface is comparatively soft, it tends to reduce irregularities in the road, by moving material from points which are relatively high to those which are relatively low; third, when used after a rain it accelerates the drying out of the road by spreading out puddles of water and thus exposing a greater area to evaporation; fourth, if the surface material is in a slightly plastic state, dragging smears over and partially seals the so-called pores which naturally occur in earthy material, and thus makes the road surface more nearly impervious to water.

To obtain the best results dragging should be done only when the surface of the road is sufficiently moist for the material moved by the

¹ See Farmers' Bulletin No. 597, "The Road Drag and How it is Used."

| NO. | ITEM | METAL | SIZE |
|-----|---|-------|--------------------|
| 1 | STEEL PLATE WITH HOLES AS SHOWN | | $1'4" \times 8'0"$ |
| 8 | BOLTS WITH NUTS AND WASHERS (COUNTERSUNK) | | 6×3 |
| 1 | WELDED EYE BOLT WITH NUTS AND WASHERS | | 6×5 |
| 2 | HOOK BOLTS WITH NUTS AND WASHERS | | 6×5 |
| 4 | WIRE NAILS | | 8d |
| 3 | WIRE SPIKES | | 30d |
| 1 | HITCHING LINK | | $\frac{1}{2}$ |
| 1 | PROOF COIL CHAIN | | $1'4" \times 8'0"$ |

| NUMBER | NO. | SIZE |
|--------|-----|--|
| | 3 | $2^{\frac{1}{2}} \times 4^{\frac{1}{2}} \times 3^{\frac{1}{2}}$ |
| | 2 | $2^{\frac{1}{2}} \times 2^{\frac{1}{2}} \times 3^{\frac{1}{2}}$ |
| | 1 | $2^{\frac{1}{2}} \times 4^{\frac{1}{2}} \times 3^{\frac{1}{2}}$ |
| | 2 | $1^{\frac{1}{2}} \times 6^{\frac{1}{2}} \times 7^{\frac{1}{2}}$ |
| | 2 | $2^{\frac{1}{2}} \times 6^{\frac{1}{2}} \times 8^{\frac{1}{2}}$ |
| | 2 | $2^{\frac{1}{2}} \times 10^{\frac{1}{2}} \times 8^{\frac{1}{2}}$ |

All wood to be of good quality seasoned white or burr oak or other timber equally as satisfactory. Cutting plate to be of medium steel. The drag to be securely made in a workman-like manner.

U.S. OFFICE OF PUBLIC ROADS

OF
ROAD DRAG
CONSTRUCTED OF SAWED LUMBER

B-14023

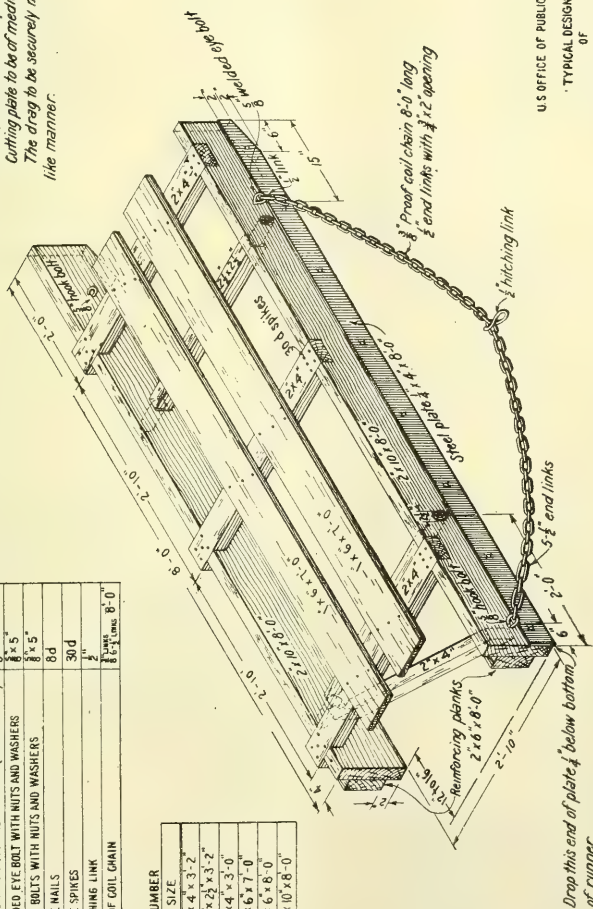


FIG. 23.

drag to compact readily after it is moved, but not sufficiently wet for traffic following the drag to produce mud.

The principal factor in successfully operating a properly constructed road drag, provided the condition of the road is favorable, is skill on the part of the operator. Such skill can be obtained only by intelligent experience, and no rules can be laid down which would enable an inexperienced operator to produce first-class results.

Under ordinary circumstances the position of the hitching link on the draw chain should be such that the runners will make an angle of 60° to 75° with the center line of the road, or, in other words, a skew angle of from 15° to 30° . But when dragging immediately over the ruts, or down the center of the road after the sides have been dragged, it may be found advantageous to place the hitching link at the center of the chain and run the drag without skew. An intelligent operator will learn quickly to adjust such details as this, as well as to shift his weight while riding upon the drag in order to make it cut where cutting is desirable, and deposit material where material is needed.

MAKING REPAIRS.

If roads of such types as have been discussed are to be maintained properly, they must frequently receive other attention than mere dragging. The side ditches should be kept open and free from vegetation, the cross drains and culverts maintained in proper condition, and worn places in the surface repaired as fast as they develop.

The material used in repairing the surface should be the same as that composing the surface and should be put on in such quantity and manner that after it is compacted the surface will be uniform and continuous. Much time and labor can be saved by making repairs as soon as needed, because when a bad place once develops in a road it generally will spread very rapidly until proper steps are taken to correct it.

COST OF MAINTENANCE.

There are not sufficient cost data available at present to warrant any very definite statements as to the cost of maintenance, but when roads can be maintained largely by use of the drag, as usually is the case with the simpler types of construction, the cost ordinarily is very small. Accurate data kept by a representative of the Office of Public Roads for road maintenance in Bennington County, Vt., during 1912 and 1913 showed that under favorable conditions a road could be dragged at the rate of about 1 mile per hour. This was where the road was comparatively well shaped and only one trip in each direction was necessary. Where more trips of the drag were re-

quired the rate was, of course, correspondingly diminished. In this county teams with drivers cost from \$3.50 to \$5 per working day of from 8 to 10 hours, and the cost per mile for dragging a road in one trip showed a corresponding variation. The number of draggings necessary per year varied over a wide range and depended on the length of time the road had been constructed and the character of the material composing the surface.

The average cost per mile of dragging an earth road 8 miles long in Alexandria County, Va., during 1911 and 1912 was \$1.25 for each dragging, which included an average of three round trips, and the total number of draggings necessary to maintain the road in good condition was 24 per year, making the average cost for dragging \$30 per mile per year. This road was maintained as an experiment by the Office of Public Roads and Rural Engineering.

APPENDIX.

TYPICAL SPECIFICATIONS.¹

The following specification clauses are intended only as an aid in preparing detailed specifications for contract work and frequently will need to be modified to meet special conditions. The general clauses and the clause covering grading are applicable to the three types of construction which have been discussed in the text, while the subsequent clauses are arranged with especial reference to sand-clay and gravel construction.

In general, all contract road work should be done under the supervision of a competent highway engineer, who, before contractors are invited to submit bids, should prepare specifications covering the work to be undertaken.

Location.—The work referred to in these specifications is to be done on the — road, beginning at — and extending in a — direction through — to —, a distance of — miles.

Work to be done.—The contractor shall do all clearing and grubbing, make all excavations and embankments, do all shaping and surfacing, construct all drainage structures and other appertaining structures, move all obstructions in the line of the work, and, unless otherwise provided in these specifications, shall furnish all equipment, materials, and labor for the same. In short, the contractor shall build said road in strict accordance with the plans and specifications and shall leave the work in neat and finished condition.

Plans and drawings.—The plans, profiles, cross sections, and drawings on file in the office of — at — show the location, profile, details, and dimensions of the work which is to be done, and shall be considered as a part of these specifications. The work shall be constructed according to the above-mentioned plans, profiles, cross sections, and drawings. Any variation therefrom, as may be required by the exigencies of construction, will in all cases be determined by the engineer. On all drawings figured dimensions are to govern in cases of discrepancies between scale and figures.

Grading.—Grading shall include all excavating, filling, borrowing, trimming, picking down, shaping, sloping, and all other work that may be necessary in bringing the road to the required grade, alignment, and cross section; the clearing out of waterways and old culverts; the excavation of all necessary drainage and outlet ditches; the grading of a proper connection with all intersecting highways; the grubbing up and clearing away of all trees, stumps, and bowlders within the lines of the improvement; and the removal of any muck, soft clay,

¹ These specifications were prepared by the Office of Public Roads and Rural Engineering largely for its own use in connection with particular projects.

or spongy material which will not compact under the roller¹ so as to make a firm unyielding subgrade or earth road surface.

All trees, stumps, and roots within the limits of the improvement shall be grubbed up so that no part of them shall be within 6 inches of the surface of the ground or within 18 inches of the surface of the subgrade, except that if they occur in an area to be covered by a fill more than 18 inches in depth they shall be grubbed up or cut off even with the present surface of the ground.

Embankments shall be formed of good sound earth or stone and carried up full width. The material shall be deposited in layers not more than 1 foot in thickness, and each layer shall be rolled¹ until thoroughly compacted with a roller weighing not less than 10 tons. All existing slopes and surfaces of embankments shall be plowed or scarified where additional fill is to be made, in order that the old and new material may bond together. When sufficient material is not available within the right of way to complete the embankments, suitable borrow pits from which the contractor must obtain the necessary material will be designated by the engineer. If there is more material taken from the cuts than is required to construct the embankments, as shown on the plans, the excess material shall be used in uniformly widening the embankments or shall be deposited where the engineer may direct. Where embankments are formed of stone, the material shall be carefully placed so that all large stones shall be well distributed and the interstices shall be completely filled with smaller stone, earth, sand, or gravel, so as to form a solid embankment.

During the work of grading the sides of the road shall be kept lower than the center and the surface maintained in condition for adequate drainage.

The grading of any portion of the road shall be complete before any surfacing material is placed on that portion, and where the plans do not call for any substantial change in the grade of any existing section of the road, the surface shall be completely scarified to a depth of 3 inches or more before the subgrade is prepared.

All excavated material² will be classed as earth and rock. Only rock in place which requires blasting for its removal and boulders of one-half cubic yard or more in volume will be classed as rock excavation.

Materials obtained from excavation and used in embankments will be paid for as excavation only, though the contractor is required to shape and trim the embankments properly. Materials obtained from excavation and used for surfacing will be paid for only once and at the price bid for surfacing material.

Quantities of materials moved in grading will be measured in excavation and the volumes determined by the average end-area method, and no payment will be made for materials excavated outside the slope lines shown on the plans unless the additional excavation is ordered by the engineer.

The contract prices for excavation shall be compensation in full for all the work which is required to be done under the heading "grading," except that an additional allowance at the rate of 1½ cents per cubic yard per 100 feet will be made for all materials of excavation necessarily hauled more than 500 feet. The centers of gravities of cuts and corresponding embankments will be used in determining the length of haul, and if the center of gravity of the

¹ For earth and sand-clay arods the rolling is frequently omitted.

² In general it is more satisfactory to classify the materials of excavation and to invite unit-price bids rather than lump-sum bids. However, if unit-price bids are invited it is important that the various quantities be accurately determined in order that the best bid may be selected. If lump-sum bids are desired, omit the following paragraphs.

cut is more than 500 feet from the center of gravity of the corresponding fill, overhaul will be allowed for the entire amount of material in the cut for the actual distance in excess of 500 feet.

Drainage structures.—[Insert specifications for necessary drainage structures.]

SPECIFICATION FOR SAND-CLAY ROAD.

Subgrade.—The graded roadway shall be brought to the elevation, alignment, and cross section indicated for subgrade on the plans, and shall be maintained free from ruts and other depressions until covered with the surfacing material.

Natural sand-clay surfacing.—The engineer will designate suitable places for obtaining natural sand-clay mixtures for surfacing.

All unsuitable material that may overlie the acceptable material shall be stripped off and removed, and this work will be paid for at the unit-price bid for stripping, measured in excavation.

The natural sand-clay mixture shall then be excavated, hauled to the road, and spread. All excavation shall be so conducted that the pits will be left in good and sightly condition, and that, where possible, provision will be made for draining the pits without additional excavation beyond their limits.

Hauling.—The hauling shall be done in wagons of approximately uniform capacity, and the loads shall be dumped at such a distance apart as will give the amount of material required to construct the surface according to the proposed cross section.

Spreading.—The surfacing material shall be immediately spread on the prepared subgrade to such depth that the surface, when compacted, will conform accurately with the profile, alignment, and cross section, as shown on the drawings. All subsequent loads may then be hauled over the surface thus formed.

The construction of the surface shall begin at that point on the road nearest the source of material and be continued from such point. In hauling over the material as deposited, wagons will be required to use the entire width of surfaced roadway so as to compact the whole section as nearly to a uniform density as possible. The teams will not be permitted to follow a single track or to form ruts.

Finishing.—After 500 or 600 feet of roadway have been thus roughly constructed the surface shall be cut up and pulverized to a depth of 2 or 3 inches with a plow or harrow and at the same time the shoulders on each side of the surfaced portion of the road shall, if necessary, be sufficiently loosened to permit of a smooth regular crown being constructed from shoulder to center of road.

When the roadway has been loosened sufficiently, the surface shall be worked with a road grader or drag to the true cross section required by the plans. This operation shall be repeated daily until the entire surface becomes smooth and firm.

Mixing sand clay.—In case the natural sand-clay mixture, as found, does not contain a sufficient percentage of either sand or clay to give a durable surface there shall be spread as much of the deficient material as the engineer may direct, and this shall be thoroughly mixed and incorporated with the material previously spread. In places where a natural mixture is not available suitable amounts of clay or sand shall be hauled, spread, and mixed as directed by the engineer.

The process of mixing may require plowing to a depth of 6 or 8 inches and harrowing with a disk or tooth harrow, and this work may be required in wet weather.

All mixing shall be classed as extra work and shall be paid for at prices bid for force account work.

The completed surface will be paid for by the cubic yard of surfacing material used, measured in excavation. So much of the surfacing material as is necessarily hauled more than — feet will be classed as sand-clay overhaul and paid for at the price bid for this item.

SPECIFICATION FOR SURFACING A ROAD WITH GRAVEL.

Subgrade.—The subgrade, or that portion of the road upon which the surfacing material is to be laid, shall consist of good sound earth brought to the proper elevation, alignment, and cross section, and shall be rolled until firm and hard. The rolling shall be done with a roller of the macadam type, weighing not less than 10 and not more than 15 tons. Should earth be encountered which will not compact by rolling, so as to be firm and hard, it shall be removed and replaced with suitable material, and that portion of the subgrade shall be again rolled. When the rolling is completed the surface of the subgrade shall conform to the cross section shown on the plans and shall have the proper elevation and alignment and shall be so maintained until the surfacing material is in place. No surfacing material shall be spread on any portion of the road until the subgrade of that portion has been prepared as herein specified.

Shoulders.—During the preparation of the subgrade, and before any surfacing material is placed thereon, shoulders shall be built of the width shown on the cross-section drawings and to a height not less than the edge thickness of the first course of gravel before it is compacted. They shall be true in alignment and shall have the edges next to the subgrade as nearly vertical as the nature of the soil will permit.¹ If intermediate courses are required, the shoulders shall be built up to receive each course in the manner described above for the first course before the material for that course is spread. Before the wearing course is spread, sufficient material shall be added to the shoulders to bring them up level with the surface of the wearing course before it is compacted and so that the shoulder when rolled will have the shape shown on the cross-section drawings. No material which contains weeds, sod, roots, or other perishable matter and which will not compact under the roller shall be placed in the shoulders. The shoulders shall be thoroughly compacted by rolling at the time the wearing course is rolled, and when complete shall be uniformly firm and unyielding and of the required shape.

Should the contractor prefer, he may build the shoulders at one operation before any surfacing material is placed on the subgrade, but if the shoulders are so built they shall be reshaped after each course is rolled and before the succeeding course is spread.

The contract price for shaping the subgrade and shoulders shall be compensation in full for all work directed to be done under the headings "Subgrade" and "Shoulders."

Shoulder drains.—Shoulder drains shall be constructed where indicated on the plans or directed by the engineer and shall be of such depth and length as may be necessary to drain water from the subgrade into the side ditches. The ditches for such drains shall be excavated just before the first course of

¹ If the material composing the shoulders should be so loose that a nearly vertical edge can not be obtained, boards may be staked in line to hold the gravel in place. As soon as the first course of gravel has been spread earth should be placed against the boards and they should be removed before any rolling is done. The general use of these boards is discouraged.

gravel is spread and shall be filled with No. 1 gravel to within 2 inches of the finished surface of the shoulder.

The contract price for shoulder drains shall be compensation in full for constructing them as above specified, except that the No. 1 gravel used shall be paid for by the ton at the price bid for No. 1 gravel in place in the first course.

Gravel surface.—On the subgrade, prepared as herein specified, shall be constructed a gravel surface of the cross section and number of courses shown on the plans, and each course when compacted shall have the thickness indicated on the plans.

Gravel.—The gravel used in this work shall consist of hard durable particles of stone mixed with sand and clay or other bonding material. Not less than 55 per cent nor more than 75 per cent, by weight, of the gravel shall consist of stone particles sufficiently large to be retained on a one-fourth inch mesh screen.

The material passing a one-fourth inch mesh screen shall consist of sand and clay or other bonding material which, when tested in the manner described in Department Bulletin No. 347, "Methods for the Determination of the Physical Properties of Road-building Rock" (p. 15), shall have a cementing value of not less than 50. This material shall not contain more than 33 per cent, by weight, of clay. The material retained on a one-fourth inch mesh screen shall be graded from fine to coarse so that not more than 75 per cent and not less than 25 per cent will pass a three-fourths inch mesh screen.

The gravel for the first course, hereafter designated as "No. 1 gravel," shall not contain any particles which would be retained on a screen having circular openings $2\frac{1}{2}$ inches in diameter. The gravel for the wearing course, hereafter designated as "No. 2 gravel," shall not contain any particles which would be retained on a screen having circular openings $1\frac{1}{2}$ inches in diameter.

Gravel obtained from the pits located at [insert location descriptions of approved gravel pits] will be acceptable under this specification, provided that, if necessary, the gravel shall be screened to remove any excess of either fine or coarse material which it may contain above the limits specified.

First course.—The first course shall consist of a single layer of No. 1 gravel, spread uniformly to such a depth that when compacted it will have the thickness shown on the cross-section drawings. The gravel shall be spread by hand from dumping boards or by dump wagons of a type that will distribute the gravel evenly over that part of the subgrade to be covered by the load or by wagons that will distribute it uniformly over the subgrade in rows containing not more than 1,000 pounds of gravel in a length of 10 feet. In order to secure the required thickness for the course, the contractor shall, if required by the engineer, set wooden guide blocks upon the subgrade at frequent intervals. These blocks shall be about 6 inches square and of a height equal to the required depth of the loose layer, and the gravel shall be spread flush with the tops of the blocks. After the gravel has been spread, as above specified, it shall be harrowed with a tooth harrow until the different-sized particles and the cementing material are evenly distributed through the mass. It shall then be rolled until it is thoroughly compacted and firm. The rolling shall begin at one edge of the course, one rear roller wheel overlapping the shoulder from 2 to 6 inches, and shall progress gradually to the center of the road in such a manner as to insure the uniform compacting of the gravel. The rolling shall then begin at the opposite edge and proceed as above. All irregularities and depressions that may develop shall be corrected immediately by reharrowing and adding No. 1 gravel, and the rolling shall be repeated, so that when the course is completed it shall be well compacted and firm and shall conform to

the required grade and cross section. It shall be so maintained until the second course of gravel has been spread.

Intermediate courses.—When intermediate courses are required, they shall be constructed in a manner exactly similar to that described above for the first course.

Wearing course.—After the first and intermediate courses of gravel have been rolled as specified the earth shoulders shall be built up or reshaped to conform with the finished cross section of the road, and the wearing course, consisting of a single layer of No. 2 gravel, shall be spread uniformly to such a depth that when compacted it will have the thickness shown on the cross-section drawings. The methods specified for spreading, harrowing, rolling, and correcting irregularities and depressions in the first course shall also apply to the wearing course, except that the rolling for the latter shall begin on the shoulder, at least 2 feet from the edge of the gravel.

When the gravel surfacing and shoulders have been rolled until thoroughly compacted and have been brought to the required cross section the surface shall be sprinkled with water from properly constructed sprinkling wagons and again rolled according to the method already described. The amount of water used shall be sufficient to wet the gravel but shall be put on in such quantity and manner as not to wet and soften the subgrade. Sprinkling and rolling shall be continued until the surface is thoroughly bonded.¹

When completed the gravel surface, shoulders, side ditches, and side slopes shall be true to the grade and cross section shown on the plans and drawings.

The contract price per ton for gravel to be used in surfacing shall be full compensation for digging, screening, loading, spreading, harrowing, rolling, sprinkling, and hauling the gravel one-half mile or less. Stripping of gravel pits will be paid for at the contract price for excavation. The contract price for overhaul of gravel will be paid on all gravel hauled a distance greater than one-half mile.

¹ If the gravel contains clay of such quality that it causes the surface material to adhere to the wheels of the roller, the surface should be sanded with coarse sand. It is advisable also to finish the surface of a gravel road, built of gravel containing clay, with a coat of sand about one-half inch in thickness, before traffic is allowed upon it.

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PROFESSIONAL PAPER

December 30, 1916

LESSONS ON POULTRY FOR RURAL SCHOOLS.¹

By F. E. HEALD, *Specialist in Agricultural Education.*²

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INTRODUCTION.

In the rural-school work in agriculture there is probably no subject which applies more of the principles of animal husbandry than that of poultry culture. This subject provides good material for instruction, is within the grasp of elementary pupils, and the home application may be made with profit in every community and by nearly every pupil.

The points of superiority of poultry study from the standpoint of home application have been arranged in chart form in figures 1 and 2. To be educational in a maximum degree the treatment of this subject should provide at least three features. There should be (1) school lessons arranged in a seasonal sequence, reenforced by (2) practical exercises in or near the school, and applied by the pupil at home in (3) a project which may or may not be club work.

¹ Prepared under the direction of C. H. Lane, Chief Specialist in Agricultural Education, States Relations Service.

² The writer is indebted to R. R. Slocum, of the Bureau of Animal Industry, for valuable assistance.

NOTE.—This bulletin is intended to assist rural school-teachers to utilize the available publications on poultry husbandry in seasonal school lessons and related home practice during the school year.

THE PROJECT.¹

Every pupil who has not already a home project or a club project should be induced to begin in September a project with a flock of hens or pullets, the size and scope of the project depending upon the maturity of the pupil, on home conditions, and on parental cooperation. One of the following cases may be met:

- (1) Purchase of a new flock by the pupil.
- (2) Flock previously reared by the pupil, possibly as a club member.
- (3) A part of the parents' flock selected and ownership transferred to the pupil.

POULTRY HOME PROJECT.

ADVANTAGES AS SCHOOL WORK:

- 1. INVOLVES ALL PHASES OF ANIMAL STUDY.
BREEDING, HOUSING, FEEDING, SANITATION.*
- 2. LIFE CYCLE OF HEN NOT LONG.*
- 3. DAILY ACCOUNTING REQUIRED.*
- 4. IMPROVEMENT RELATIVELY EASY.*
- 5. EASILY COORDINATED WITH PLANT PROJECTS.*
- 6. CORRELATES READILY WITH OTHER BRANCHES.*
- 7. ELASTICITY IN AIM, SIZE OF FLOCKS, AREA ETC.*
- 8. PARENTS READILY COOPERATE.*

FIG. 1.—Chart showing value of poultry as a school subject.

- (4) Management of the above without ownership.
- (5) Management of the entire farm flock.

Ownership or partnership is very desirable, so that the interest may be keener and the lessons better learned.

Have an agreement (written, if possible) with the parents as to the plan of cooperation and the terms of ownership, profit sharing, etc.

¹ The term "home project" applied to instruction in elementary and secondary agriculture, includes each of the following requisites: (1) There must be a plan for work at home covering a season more or less extended; (2) it must be a part of the instruction in agriculture of the school; (3) there must be a problem more or less new to the pupil; (4) the parents and pupil should agree with the teacher upon the plan; (5) some competent person must supervise the home work; (6) detailed records of time, method, cost, and income must be honestly kept; and (7) a written report based on the record must be submitted to the teacher. This report may be in the form of a booklet. The club project should be identical with the home project from the school point of view.

Plan that each pupil who starts with scrub poultry shall try to work into pure-bred stock, if possible. This may be done by substitutions or at hatching time. Parents who are interested will vouch for the time records and accounts of the pupils. Arrange for the supervision of the work and, if possible, the occasional visit of some person expert in poultry raising. The local or county club leader or the county agricultural agent may help to arrange for this supervision.

POULTRY HOME PROJECT.

ADVANTAGES AT HOME:

- 1. INVESTMENT MAY BE MODERATE.*
- 2. INCOME BEGINS EARLY.*
- 3. LABOR SUITED TO YOUNG PERSONS.*
- 4. UTILIZES HOME AND FARM WASTE*
- 5. WEED SEEDS AND INSECTS DESTROYED.*
- 6. CONTINUALLY SUPPLEMENTS FOOD SUPPLY.*
- 7. POSSIBLE ON LIMITED AREAS.*
- 8. SUITED TO BOTH BOYS AND GIRLS.*
- 9. DISPOSAL OF ANIMALS NOT REQUIRED FOR PROFIT.*

FIG. 2.—Chart to balance figure 1, from the home point of view.

Whenever projects are not taken, have as many practical exercises as possible to illustrate the lessons.

THE PROJECT REPORT.

Whenever any single phase of the project is completed, the pupil should be required to write a report on that section. A skillful teacher will be able to have some of these reports written as language exercises under such titles as "How I selected my poultry flock," or "Feeding my flock of laying hens." The labor, feed, egg, and other records should be compiled and balanced each month as arithmetic practice. Toward the end of the school year have the pupils

assemble these reports and records, together with selected pictures, and fasten them within heavy covers as the "booklet" or the final project report. See forms pages 30-32.

ORGANIZED CLUB PROJECTS.

The State agent in charge of club work at the State agricultural college will cooperate with the local teacher in the organization of poultry clubs and will usually help to arrange for the supervision of home work, which is the most difficult problem in practical agricultural instruction. Farmers' Bulletin 562 is devoted to this subject. New poultry clubs are usually organized about January 1, but the pupils should not postpone all home work until that time.

School credit for the home project should preferably be given as a part of the rank for the course in poultry. In such a case the home project becomes fundamental and the school lessons a means toward accomplishing the practical end, so that the rank and credit are given on the work as a whole. The weight given to this credit is not to be in proportion to the number of fowls kept, but, assuming that enough are kept to make the work worth while, in proportion to the phases of poultry management developed and the application of principles learned. The subject of school credit for home practice in agriculture is developed in United States Department of Agriculture Bulletin 385.

CHARTS AND CHART MAKING.

Most of the illustrations in this bulletin are chosen with a view to showing teachers how to provide charts, models, and other illustrative material as well as how to illustrate poultry topics. Large sheets of manila paper or cloth charts may be used. Lettered charts, such as figures 1 and 2, may be used to emphasize certain principles. District surveys may be arranged on chart forms such as those given on page 25, but should also be put on a copy of the district map as is suggested in the census map in figure 3. Do similar work for other animals and crops.

Relative gains and losses, total productions, and other results may be charted by the graphic method shown in figure 10 (p. 17), especially where the fluctuations during a period of time are not taken into account. Fluctuations may best be shown on a vertical chart as in figure 7 (p. 13). Have the pupils practice first in charting the rise and fall of the daily temperature and then make graphic records of the laying of their home flocks. This will enable them to interpret such charts as figure 8 which shows the effect of animal feed in the ration.

Pictures selected to show contrasts may be cut out of farm papers and mounted as in figure 4. In some cases it may be desired to contrast two varieties of fowls which are somewhat alike.

Such charts as figure 5 may be enlarged with or without the lettering and used for class drill. Have pupils assist in this chart-making and apply the same ideas to other animals. Such a chart as figure 13 (p. 22) is not intended to take the place of practice in the process but may be used for a preliminary lesson, and, by remaining before the class for some time, will fix the facts firmly in mind. A convenient size is about 24 inches wide, the length being determined by the subject.

Such illustrations as figure 9 are best made with objects instead of pictures. Have the facts at hand to teach the whole lesson. Compare average poor results with results which are reasonably obtainable. In figure 9 (p. 15) the best production represents only a 50 per cent yield, which however is quite good and is the average of 2,000 hens. Such a comparison does not invite criticism.

Have pupils make working drawings of all equipment before making the article itself. Such drawings as figure 8 make good charts, and models should be made at school or at home. Models of small articles should be made full size, but it is often desirable to construct a model of a new type of house at school, leaving one portion unfinished as is shown in figure 6.

In every case the teacher should use the pupils so far as possible instead of doing all these things himself. Some very helpful charts may be copied from those issued by commercial concerns.

THE DISTRICT SURVEY.¹

At the beginning of the school year the teacher should obtain all the information possible as to the poultry in the district. The pupils may assist in obtaining this information, but it is quite essential that the teacher become personally acquainted with his district. When the first data are collected two large charts should be prepared, one on a ruled form and one on a map of the district. These may be prepared and filled in by the pupils under the direction of the teacher. If no map of the district is to be found, one may be drawn and corrected by the pupils and several copies made on large sheets of manila or oak-tag paper for survey purposes. On one map indicate the homes of the pupils. Use small colored seals or pins to indicate the breeds or varieties of fowls on each farm, and mark the number kept. (See fig. 3.) Later indicate sources of feed, method of incubation, and other data.

Fill the first chart in September but collect further data as new practice becomes seasonal. Some of the following data should be obtained concerning each farm in the district: Size of farm, location, owner's name; breed, variety, and strain of poultry kept; pure-bred

¹ Suggested survey forms will be found on page 25.

or scrub; number of adult hens, adult males, this season's chickens at date; method of incubation; aim, commercial or domestic; number of fowls to be fattened for market; improvements planned for this season.

REFERENCES.

Nearly all the subject matter for class discussion and instructions needed for home-project work will be found in bulletins available either free or at a nominal cost. Nearly every State agricultural college has published one or more poultry bulletins, and in many cases the extension service of the college has issued circulars suited to school use. These should be obtained by addressing the dean of the agricultural college.

The Farmers' Bulletins of the United States Department of Agriculture cited in this bulletin cover most of the topics to be studied



FIG. 3.—Map chart of all fowls on farms—census of 1910. (Similar charts of farms in district are suggested.)

and are suited to the pupils' reading and study. Bulletins in this list will be sent free, so long as the supply lasts, to any resident of the United States, on application to his Senator, Representative, or Delegate in Congress, or the editor and chief Division of Publications, United States Department of Agriculture, Washington, D. C. Because of the limited supply, applicants are urged to select only a few numbers, choosing those which are of special interest to them and ordering but one copy of each. When this free supply has been exhausted, a limited number are yet for sale. One should apply to the Superintendent of Documents, Government Printing Office,

Washington, D. C., who has these bulletins for sale at 5 cents each. Some other publications of this department are for sale by the Superintendent of Documents, but these are more often technical bulletins, of interest only to those who wish to specialize in the subject. Classified lists of department publications on different phases of agriculture for teachers' use are issued by the Agricultural Instruction Division, States Relations Service, United States Department of Agriculture.

Several of the textbooks on poultry raising are suited to the needs of the teacher, and some of the more elementary texts may be used by the pupils for reference.

Good pamphlets are issued by some of the poultry-supply houses, and some are supplied free to teachers. One of the best ways to keep these bulletins ready to use is to file them in pasteboard cases which may be made for the purpose, grouping the bulletins by subjects. Some poultry journals are usually to be found in the pupils' homes, and the poultry columns of other farm papers will be found helpful. Encourage pupils to bring these to school.

ILLUSTRATIVE MATERIAL.

On a chart of the size used for surveys have some pupil copy a diagram showing the points of a fowl. Collect pictures of prize-winning fowls, and diagrams and photographs of poultry houses and equipment. Procure and preserve samples of as many kinds of poultry feed as may be of local interest. The boys may be glad to make models of some needed poultry equipment. (See Farmers' Bulletins 586 and 606 for information about collecting and preserving illustrative material.)

Modifications due to climate in different sections must be made in considering any bulletins not prepared especially for the locality in which the school is located. Such modifications concern types of shelter, dates of hatching and brooding, green crops, and especially winter management. For this reason it is wise to depend as far as is convenient on the publications of the State agricultural college and experiment station and to consult the poultry experts of that institution. The State club leader will give practical assistance along these lines, especially in the matter of home practice.

Special phases of poultry raising for districts raising ducks, geese, turkeys, and guinea fowls are not developed in this bulletin. The method of study here outlined may be modified by the teacher to fit such cases, and Farmers' Bulletins 200, 684, 697, and others, with bulletins published in the State, will give the subject matter needed.

LESSON ONE.

SUBJECT: SELECTING THE FLOCK.

EARLY SEPTEMBER.

Topics for study.—(Develop only those which may have local application.)

(1) The individual fowl: Characteristics indicating strong constitutions, faults or defects to be avoided, value of desirable ancestry, relative value of hens and pullets. (See fig. 4.)

(2) The breed and variety: Develop the application of the terms *breed*, *class*, *variety*, and strain as applied to poultry. Find what varieties and strains are considered successful locally and study these more carefully. What color of egg does the local market demand?

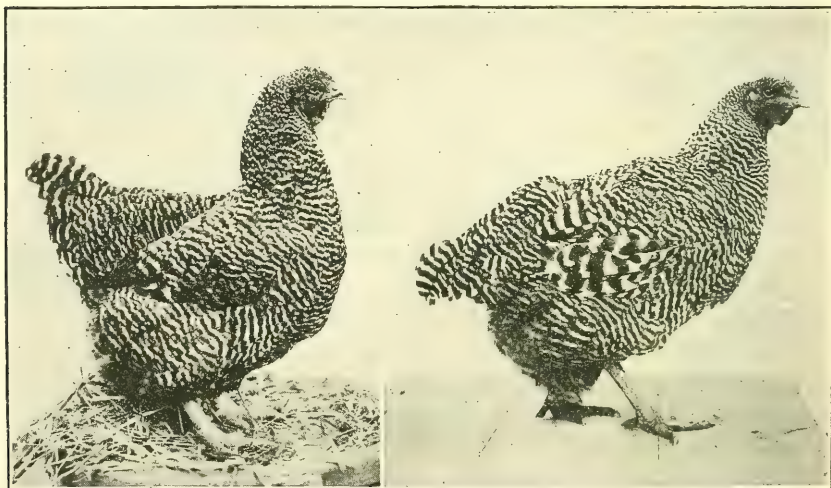


FIG. 4.—Evidences of strong and weak constitutions, showing method of arranging pictures for contrast.

Consider the aims of the pupils in their projects in covering this topic.

References.—Farmers' Bulletins 51; 287, pp. 5, 6; 355, pp. 29–33; 562, p. 7. Also station and extension bulletins and circulars of the State agricultural college. "The American Standard of Perfection" is the authority for judging breeds and varieties.

The home project.—Have each pupil begin the project at once. Decide on aim in each case—eggs for market, meat for market, eggs for hatching, eggs and meat for home. Help pupils to obtain expert advice in selecting their project flocks. Cull at once and plan to dispose of the culls in accordance with suggestions of Lesson three.

Material and exercises.—Use photographs and other pictures of poultry. Typical feathers showing markings of breeds, etc., may be collected and mounted. Complete and use the survey charts and

maps. The teacher should visit one of the fairs with his class, if possible, and study the poultry as well as other exhibits. Take a class excursion to a farm where a successful poultryman will assist the class.

Correlations.—Utilize the related topics in the other school subjects. Examples of this may include the history of the breeds and

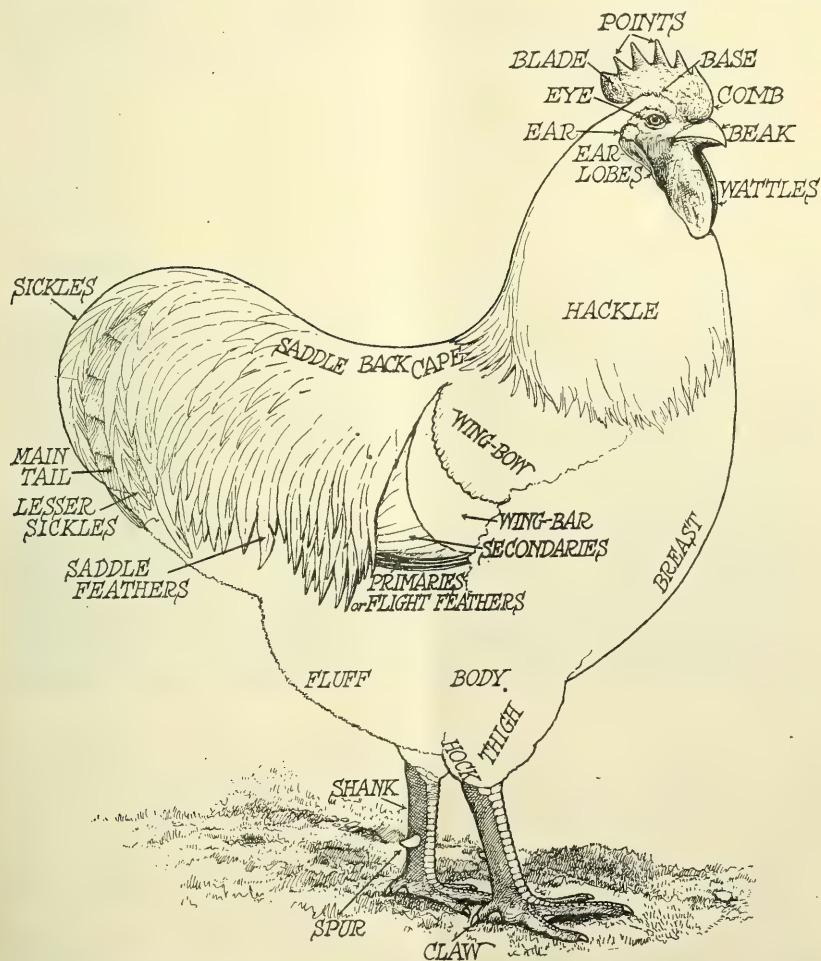


FIG. 5.—Glossary chart giving the names of the various sections of a male fowl. A study chart. For drill, omit lettering.

NOTE.—In the female the cushion takes the place of the saddle of the male and the sickle feathers are absent.

the geography of their origin. Language lessons may include descriptions of typical fowls or a report of observations at the county fair. In arithmetic consider the gain on 150 eggs yearly per hen when the eggs of the required color sell for 3 cents a dozen more than other eggs. Find how many more eggs per year will be required to offset extra

price for pure-bred pullets. Compute number of extra eggs needed to offset the value of 3 pounds 4 ounces extra weight on each hen, poultry selling at the local rate. Have pupils enlarge figure 5 as a chart, possibly not putting the names of points on the chart.

Make out inventories for project or club work, including value of fowls, house, and equipment. (See also U. S. Department of Agriculture Buls. 132, Correlating Agriculture with the Public School Subjects in the Southern States, and 281, Correlating Agriculture with the Public School Subjects in the Northern States.)

LESSON TWO.

SUBJECT: DISPOSING OF CULLS.

EARLY FALL.

(Omit this lesson if no pupil in the class has an opportunity to apply it in his project or with his parents' flock.)

Topics for study.—What shall be culled out of the farm flock? What older fowls shall be kept? How many males are needed? Are the culls for market or for home use? Fatten and market as early as possible. Show loss from boarding the culls too long. What will the market accept? How does the local market demand that the poultry shall be prepared?

Fattening rations. Restricted range. Shipping alive. Dressed poultry. Individual customers. Parcel-post shipment. Local market prices. Poultry for home use. Value of poultry as food. The economy of a home-grown meat supply. Select topics needed and read references.

References.—Farmers' Bulletins 287, pp. 34-41; 355, pp. 29-39; 562, p. 11; 635, pp. 11, 12, 21.

Home projects.—Consult with each pupil and plan that each one may carry out such phases of this lesson as fit his case. The older pupils would gain much from the business practice involved in marketing.

Exercises.—A trip to observe marketing methods is helpful whenever pupils are to have this work to do.

Correlations.—Compare the price the farmer gets for poultry with the retail price. Compute the percentage loss to farmers who sell poultry and buy meat at retail. Weigh a flock of culls and compute present market value. Find present daily cost of food and compute gain or loss if the present flock gains 1 pound per fowl and sells at 1 cent more per pound on November 20. Demonstrate that it pays to sell early, but to keep a good supply of meat for the home. Compute each bill of poultry sold by pupils.

Have pupils write letters requesting such bulletins as each needs.

LESSON THREE.

SUBJECT: POULTRY HOUSES AND YARDS.

OCTOBER.

Topics for study.—Divide the study if some of the pupils are to construct new houses.

(1) Old houses: Drain the floor, replace earth and litter with fresh material. Procure sufficient light and ventilation. Clean out all rubbish. Disinfect roosts, nests, and other equipment. Whitewash the inside walls of the house. Be sure roof will not leak. Reconstruct any roosts, nests, etc., which are unsuitable.

(2) New houses: What location for light and drainage? What relation to yards and other buildings? How much floor space? Style of house. Best roof for the location. What arrangement of

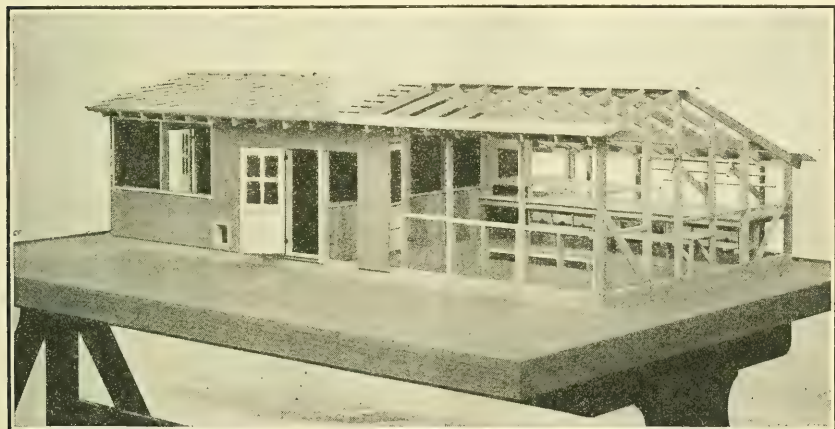


FIG. 6.—A model of a poultry house used on the Government farm at Beltsville, Md., suggesting how pupils may make models.

doors, windows, and open spaces? Ventilation how? Best arrangement of nests, roosts, and equipment.

(3) Yards and fences: Value of free range. Value of alternate yard system, one growing crop and one being pastured. Relation of fencing to the breed of fowls. Fencing for or against chicks. Fall green feed in yards. Fall sowing in alternate yard for spring feed (see p. 28). Value of the orchard as a range.

References.—Farmers' Bulletins 574; 287, pp. 7-19; 355, pp. 21-25; 682; 480, pp. 8-16. Nearly every State has literature on houses adapted to its own climate.

Home projects.—Each pupil should arrange at once for the proper housing of his flock. Have each apply the lessons learned from the references. Keep daily accounts of expense, feed, labor, and income. See forms pages 30-32.

Material and exercises.—Select pictures and plans of houses from reliable sources. Have pupils inspect some good houses and make a class excursion for this purpose where it is feasible.

Correlations.—Descriptions of buildings and equipment or the story of making the house will provide good language work. Plans, perspectives, and working drawings are practical work. Problems in areas, lumber bills, and inventories should be drawn from the projects of the pupils.

Manual training should include making nests and feed hoppers. Models of good styles of houses may be made, especially the model of the State college type. Such a model developed in the United States Department of Agriculture is illustrated in figure 6. This type of house has been made and used under the direction of the Poultry Division of the Bureau of Animal Industry. It has been found satisfactory on the Government farm at Beltsville, Md. A model of a selected type may be made by the pupils.

LESSON FOUR.

SUBJECT: POULTRY FEEDING.

NOVEMBER.

Topics for study.—Elementary principles of feeding. Available nutrition in different material used for poultry foods. Requirements for growth, renewal of tissues (especially feathers), warmth and egg production. Balancing a ration. Substitutions to save expense. Sources of animal food.

The necessity of animal food is plainly shown in figure 7, in which the production of eggs is seen to be much greater in pens fed on either beef scrap, fish scrap, or skim milk than in the check pen where the ration contained no animal food.¹

The rations used in obtaining these results over a period of four years were as given below:

Rations to test the effect of animal food for poultry.

| Ration. | Check pens. | Skim-milk pens. | Meat-scrap pens. | Check pens. | Skim-milk pens. | Fish-scrap pens. |
|-----------------|----------------|-----------------|------------------|----------------|-----------------|------------------|
| | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> | <i>Pounds.</i> |
| Corn..... | 10 | 10 | 10 | 10 | 10 | 10 |
| Wheat..... | 10 | 10 | 10 | 5 | 5 | 5 |
| Oats..... | 5 | 5 | 5 | 10 | 10 | 10 |
| Brans..... | 5 | 5 | 5 | 5 | 5 | 5 |
| Shorts..... | 5 | 5 | 5 | 5 | 5 | 5 |
| Skim milk..... | | 62 | | | 50 | |
| Meat scrap..... | | | 3.5 | | | |
| Fish scrap..... | | | | | | 3.5 |

¹ Adapted from Purdue University, Indiana, Bul. 182, Nov. 1915.

The material used in the rations was such as might be practical on the average Indiana farm. More ideal rations are often too expensive. To these rations were added grit, shell, and green food. The chart

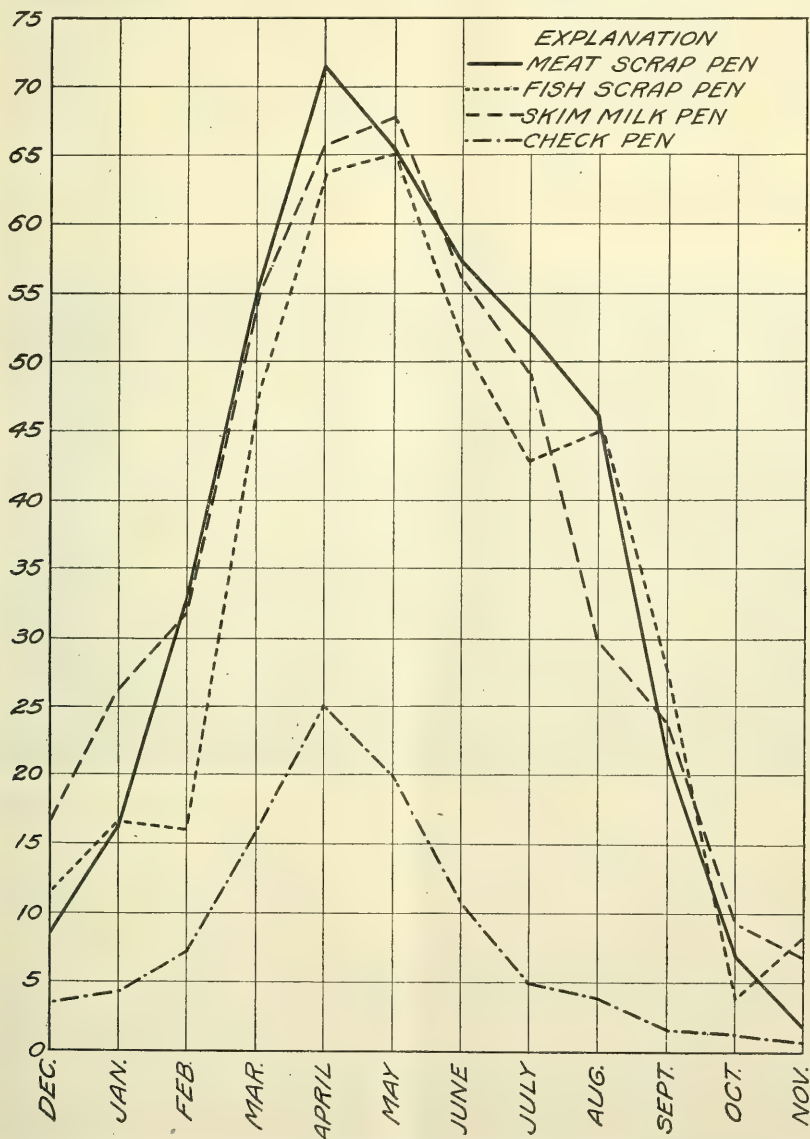


FIG. 7.—Average per cent egg production per month per pullet, with and without animal food. Graphic type of chart for results of several factors. (Adapted from investigations of Agricultural Experiment Station of Purdue University, Lafayette, Ind., Bul. 182.)

does not bring out the relative value of meat scrap, fish scrap, and skim milk, but shows the necessity for some animal food. Skim milk is often cheaper than other forms of animal food.

Value of dry mash, green food, grit, shells, charcoal. Why a scratch feed? Why have a variety? Quantity of feed needed? How obtain succulent food? How provide water? To what extent shall wet mashes be used? How feed the layers and the breeding flock? Avoid diseases of the digestive tract. Avoid spasmodic feeding of green foods which leads to overeating. Feed hopper approved by the U. S. Department of Agriculture is shown in figure 8.

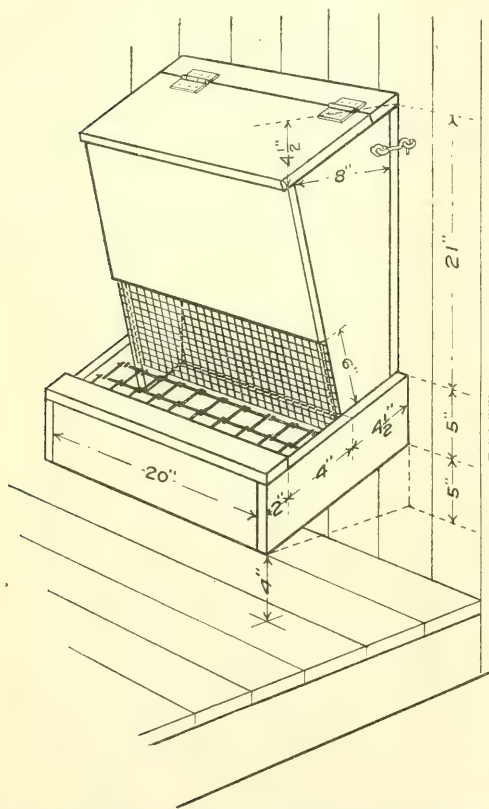


FIG. 8.—An efficient feed hopper, tested by the Bureau of Animal Industry. (Suitable drawing and manual correlations are suggested.)

References.—Farmers' Bulletins 287, pp. 20–26; 355, pp. 35, 36; 528, p. 10. State agricultural college bulletins are especially valuable on feeding.

Home projects.—Have each pupil arrange for feeding his flock rations which best fit his own circumstances, considering the available home-grown feed, local prices of grain, supply of table scraps or other by-products to be obtained. The purpose of the flock should be kept in mind as well as the relative protection from the winter's cold. Have feed records kept constantly and reported occasionally. Weight should not be estimated. Labor record should be kept. See record forms, pages 26–32.

Material and exercises.—

Have samples of as many poultry foods as possible brought to school. Classify and study these and arrange them for the permanent school collection. Have some members of the class post each week the list of prices of all the grain and other feed for poultry, using local retail prices. Make a list of home-grown feeds and give the price at which the farmer might sell each. Change this list as prices change.

Correlations.—Compute the cost of different rations used. More mature pupils may compute the balanced rations, but so many mixtures have been computed by experts that it is not necessary for the amateurs to learn this detail.

Lessons on human hygiene, food, and digestion should be correlated with those on poultry feeding, since the same principles apply in each. A knowledge of one topic leads to an appreciation of the other. In drawing classes have plans made for equipment (as in fig. 8), and manual-training classes should make models to be used at home.

LESSON FIVE.

SUBJECT: WINTER MANAGEMENT OF POULTRY.

EARLY DECEMBER.

Topics for study.—Consider the need of dry floors, proper litter, dust boxes. Provide ventilation. Use of open front instead of windows.

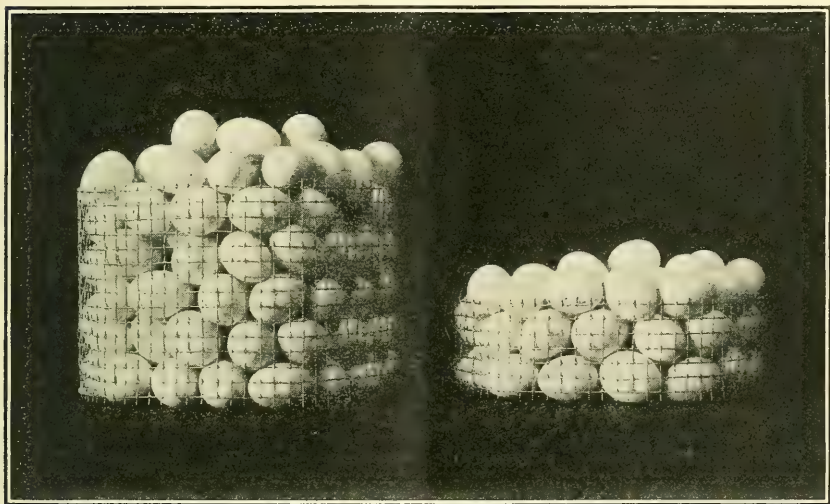


FIG. 9.—An exhibit arranged to contrast what the average farm hen lays and what selected hens lay when properly cared for. Ratio, 85 to 151.

Value of sunlight. Ample range, especially for breeding flock. Provide exercise for all. How control range of temperature? Cleaning nests, litter, and dropping board. (See management of poultry manure on p. 29.) Watch roosts and nests for mites, lice, and spiders. How disinfect? How sterilize water fountain? Variations in diet during very cold weather. Watch for signs of broodiness and use "broody coops." Separate breeding stock from other laying hens. Keep males from flock which lays market eggs. Keep a daily record of everything. The importance of records may be seen by referring to figure 9.

In five egg-laying contests held in 1915, 2,375 hens laid an average of 151 eggs, while it is estimated that the average for farm hens in this country is not over 85 eggs per year. This average of 151 eggs included several hens which laid no eggs and several which laid over 200 eggs, the highest record being 314. It seems fair to claim that the

farm hens ought to average 151 eggs, as that is about 42 per cent of a perfect score and is less than 50 per cent of the highest record actually made. Without doubt both breeding and management figure in the improvement over average records.

A graphic presentation of the 151-egg yield compared with the 85 eggs which the average farm hen lays is suggested in figure 9.

References.—Farmers' Bulletins 287; 355, pp. 34–38.

Home projects.—Each pupil should carry out every point in management which applies to his project. Records of labor, feed, eggs, and sales should be kept with care and brought to school for the correlation work. If diseases or pests appear, consult the references and call on specialists at the State college of agriculture.

Exercises.—Have pupils individually visit the more prominent poultry establishments and report on the management. An evening talk or illustrated lecture for the public may be arranged. Farmers' institute lectures with lantern slides are available in the States Relations Service, United States Department of Agriculture.

Correlations.—Use the pupils' labor, feed, and income records for arithmetical problems. Have each pupil make a balanced statement of cost and income at the close of each month. Have the story of the management of the month written with care and credit it as a language lesson.

LESSON SIX.

SUBJECT: POULTRY DISEASES AND PESTS.

DECEMBER.

Topics for study.—(1) Digestive disorders: Prevent by using clean utensils, pure water, clean food, balanced ration, moderate use of new foods, keeping sparrows away.

Signs: Lack of vigor, droppings unusual in appearance or odor, failure to feed well, unnatural appetite.

(2) Diseases due to poor ventilation, overexposure, and dampness, may be prevented in most cases. Contagious diseases may appear and the fowls so affected should be isolated and expert advice gained. A discussion of different diseases is not necessary, but any disease which becomes prevalent should be studied.

The treatment of lice, mites, spiders, and other animal pests is found in the publications used for references. Banish the English sparrow, provide a dust box, keep things clean, and disinfect frequently.

References.—Farmers' Bulletins 530; 287, pp. 42–47; 528, p. 11; 493; Bureau of Entomology Circulars 92, 170.

Home projects.—Careful watching and preventive practices are important. Pupils should take particular notice of each bird each day. Clean roosts and nests, sterilized feed and water utensils, pure

water and clean food will prevent many troubles if the pupils persist in such practice. Neglect to open windows during the day results in high temperature and poor ventilation, rendering the fowl susceptible to colds, roup, and other troubles. Help pupils to get advice as to any diseases which appear.

Correlations.—The school course in physiology and hygiene includes topics in relation to digestion, respiration, ventilation, and general sanitation. Many of these principles apply equally well to poultry and other animals, and this correlation will prove helpful to both subjects. If a poultry club is to be organized, have the pupils write letters applying for membership, information, etc.

LESSON SEVEN.

SUBJECT: EGG SELECTION.

JANUARY.

Topics for study.—(1) Separation of breeding flock from layers. Elimination of males from laying flock. (See fig. 10.) Frequent, regular, careful collection of eggs.

(2) Market eggs: What to select. Clean, uniform eggs. Test any doubtful eggs. Avoid freezing. Grade to conform to best

PERCENT LOSS OF FARM EGGS

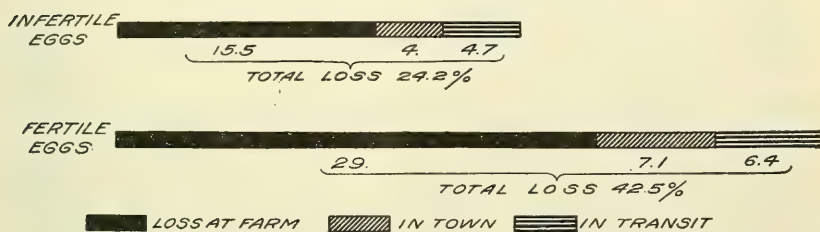


FIG. 10.—Horizontal graph teaching the desirability of infertile eggs for market.

local market. Show the loss resulting when a few low-grade eggs lower the grade of a whole case. How shall we dispose of the culled or defective eggs?

(3) Eggs for incubation: The source. Selection and breeding. Use only high-class fowls. Begin now to grade up to pure breeds. Pure-bred males from other flocks are desirable. Necessity of vigorous constitutions. Handling the eggs. When begin to save for hatching? How long may they be kept? What temperature is best? It is much better to buy eggs for hatching than to use eggs from scrub fowls.

References.—Farmers' Bulletins 528; 562; 287, p. 40; 594, pp. 1-4; 682. The State agricultural college is the best authority concerning the climate and other local factors which may determine the time for hatching. Consult State agricultural college bulletins.

The home projects.—Have each pupil learn to apply methods adapted to his needs. Clean nests, frequent collections, and careful handling of eggs, sorting and packing for market are things a boy may grow careless about. Have all plans for incubation made before it is too late to do this well. A few well-selected fowls in a breeding flock may prove the nucleus of pure-bred flocks for the whole community. The lesson taught in figure 10 should be deeply impressed, because the margin of profit is small, usually due to the loss of fertile eggs. While this loss is greater in summer, yet the same principle holds at all seasons.

This is the month to organize or reorganize a poultry club. Refer to Farmers' Bulletin 562 and address the State leader of club work (at the State college of agriculture), requesting his assistance.

Exercises.—Demonstrate egg testing. Have pupils practice this first at school and then at home. Have them bring to school samples of eggs which have defects that make them unmarketable. If possible, have some successful poultry breeder give the class a talk on these topics.

LESSON EIGHT.

SUBJECT: INCUBATION.

EARLY FEBRUARY.

Topics for study.—What is the best time for incubation in this district, considering the climate, facilities for brooding, etc.? What influence has the market on the time for incubation? What should be known of the breeding stock? What eggs to discard? Care of eggs for hatching. Selecting the hen and preparing to set her. The process of setting the hen. How feed and care for the setting hen? Testing the eggs for fertility about the seventh day. Management during the last three days and bringing off the brood.

In case any of the pupils are to use an incubator, study its principles and manner of working. How start the incubator? Temperature control, testing the eggs, moisture control, final steps in hatching. How dispose of infertile eggs?

References.—Farmers' Bulletins 585; 562, pp. 8-10; 528, p. 8; 287, pp. 27-30; 682. Use State agricultural college bulletins constantly. Commercial houses, poultry-supply dealers, and others publish much useful material.

The home projects.—Have the pupils carry out with care the best obtainable advice on each step connected with this part of their projects. Incubation is a critical process. It is the opportunity to introduce pure-bred stock. Carelessness during the incubation period endangers the success of the next year of the project. This part of the project should rarely be omitted, although there are circumstances under which it is wise to buy chicks instead of running an incubator.

Exercises.—Utilize pamphlets issued by poultry-supply houses. If many pupils are to use an incubator, it may be desirable to have a demonstration at school or elsewhere.

The teacher should not take the authority to have an incubator run at school, because of fire risks.

Correlations.—Locate the sections which make a specialty of high-grade eggs for incubation, using advertisements and articles in poultry papers for information. Inquire into the history of artificial incubation. Compute the added profit and rate of gain for each pupil if all the eggs from his flock for one stated month had been sold for incubation at \$1 a dozen.

LESSON NINE.

SUBJECT: MARKETING EGGS.

EARLY MARCH.

Topics for study.—What does the market demand as to color, grade, and style of packing of eggs? How gather? How sort and grade?

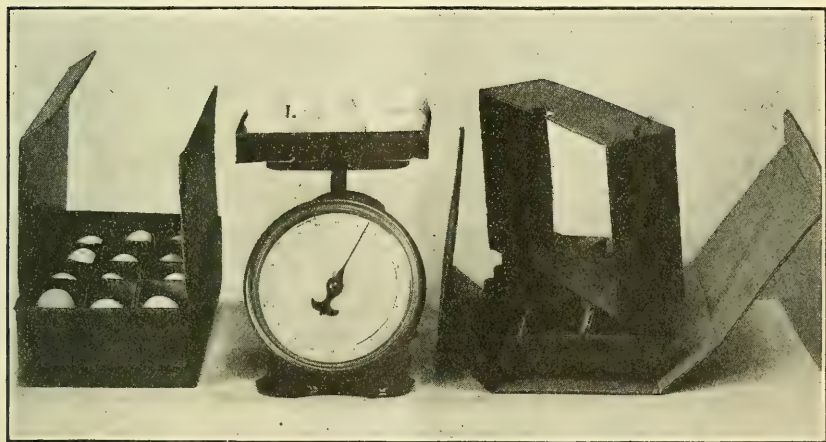


FIG. 11.—Some of the apparatus needed in teaching parcel-post shipment of eggs.

How and when test eggs? What shall be done with eggs from a stolen nest? Be sure to remove males from laying flock.

Delivery of eggs. Individual customers. Selling to local retailers or to hucksters. Dealing with commission houses. The community egg circle. Stamping and dating eggs. Shipping by parcel post; by express. Protection from heat and from other damage. Avoid loss from poor grading and obtain a reputation for a high-class article. Sell frequently, especially on a falling market.

References.—Farmers' Bulletins 287, p. 40; 528, pp. 10, 11; 562, pp. 10, 11; 594; 656; 682; Farmers' Institute Lecture No. 17, U. S. Department of Agriculture.

The home projects.—Have the pupils who are to market their eggs learn and put into practice the principles laid down in the references and make note of any gain resulting from correct practice. This practice of the pupils may initiate better practice throughout the community. A community reputation may be a valuable asset.

Practical exercises.—Procure and examine samples of shipping crates, especially for small lots. Keep this as a school exhibit as long as is wise. Collect and tabulate, as a part of the survey, information as to egg production and marketing in the district.

Correlations.—Have pupils write out as a language exercise a description of the methods used in marketing eggs. Have problems

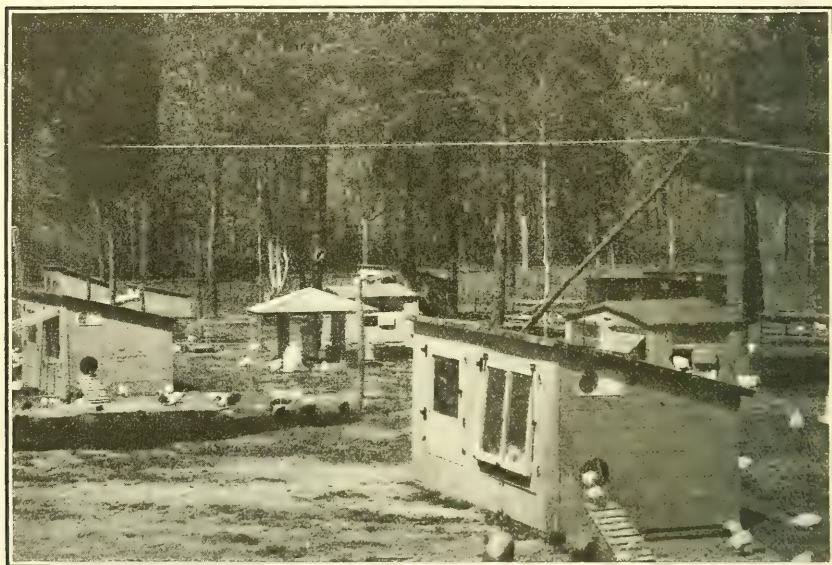


FIG. 12.—Brooder practice on the Government farm at Beltsville, Md. Observation of such practice is desirable for each class.

based on the project records of the pupils to demonstrate the value of the methods advised by the expert poultry men. Figure 11 illustrates facts in parcel-post shipments, although dozen lots do not make economical shipments. A general discussion of parcel-post shipments is found in *Farmers' Bulletin* 703.

On the State and county maps locate the markets for local eggs and the routes used in reaching them. Use inks of different colors.

LESSON TEN.

SUBJECT: BROODING OF CHICKENS.

MARCH OR APRIL.

Topics for study.—Take up the subject of natural or artificial brooding in accordance with the projects of the pupils and the practice of the district. How care for the chicks the first 48 hours after hatch-

ing? When, what, and how shall they be fed? Early practice with hens; with incubator chicks. The use of hovers. Management of artificial brooders. How keep the brood free from vermin? Brood coops and management. (See fig. 12.) How feed the growing chickens? What range is desirable? Protection from birds and animals of prey. How avoid chicken diseases? (The date of incubation varies with the climate and the market demands, and this lesson should be taken up before the time for chicks to appear.)

References.—Farmers' Bulletins 287, pp. 30-33; 528, p. 8; 624.

The home projects.—Have individual conferences with the pupils and help each one to obtain the assistance he needs with his project. This stage of the work varies much and is critical. Take a field trip which shall include a visit to farms where good brooders may be seen. Take photographs of good brooders.

Call upon the county agent and the club leaders for help on the practical problems of the pupils.

LESSON ELEVEN.

SUBJECT: PRESERVING EGGS.

WHEN EGG PRICES FALL.

Topics for study.—When does it pay to preserve eggs? Methods used: Bran, lime, salt, limewater, water glass, cold storage. Water-glass method simple and effective. How much of a range between preserving and using price is necessary to warrant the preserving of eggs? Why should preserved eggs not be sold to merchants? May they be sold to individual customers, if facts are told? Read with care the method of preserving eggs. What cautions as to use of eggs preserved in water glass? Eggs preserved during the low-price period at less than 20 cents a dozen may be used by the family when the market price is high, thus releasing for sale the entire output of fresh eggs. When the market price is extremely high, a good profit may be made by selling some of the preserved eggs, properly designated, at a price somewhat below the price of fresh eggs.

References.—Farmers' Bulletin 287, pp. 41, 42.

The home projects.—After the method has been demonstrated in a school exercise have the pupils obtain the material and put down in water glass at least a few eggs. When this practice is once begun, the family may easily continue it. The beginning is the chief difficulty. It may be more economical for several pupils to buy the commercial water glass in larger quantities and divide it. One dealer sold pints for 15 cents, quarts for 25 cents, and gallons for 80 cents.

Practical exercises.—At school boil 1 quart of water to sterilize it. Mix with this when cool about 4 ounces of commercial water glass.

Fill a large-mouthed 2-quart jar with selected eggs and pour the liquid over them to fill the jar. Fill with a little sterilized water if necessary. Seal and label properly. After this has remained at the school long enough to make its impression, allow the pupil furnishing the eggs to take them home. Make a chart by copying figure 13 on large manila paper.

Correlations.—Make arithmetical problems out of the following data, substituting local prices if it is desired. April eggs average 20 cents a dozen, May eggs 18, June and July eggs 16, August eggs 20. October sales quoted 25 cents, November 30, December 35, January 40, February 35. One quart of water glass costing about 25 cents will make 10 quarts when diluted and will preserve as many as 12 or 15 dozen of eggs. Find saving if May eggs preserved as suggested are used in December. Preserve 10 dozen eggs in May, 20 dozen in

PRESERVING EGGS WATER-GLASS METHOD

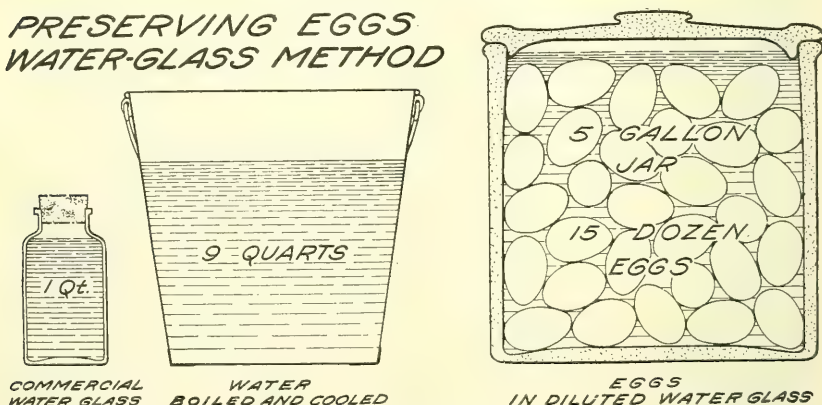


Fig. 13.—Chart to be used to fix in minds of pupils a method of preserving eggs.

June, and 10 dozen in July. Use half in January, half in February. How much is saved? When fresh eggs sell at 35 cents, preserved eggs will bring from 25 to 30 cents.

LESSON TWELVE.

SUBJECT: RAISING CROPS FOR POULTRY.

APRIL.

Topics for study.—(1) Crop rotations for forage in alternate yards. (See Supplement.) Oats, rye, alfalfa, clover, lettuce, Swiss chard, dwarf Essex rape, and other green crops may be sown in one yard while the flock uses the other. (See p. 28).

(2) Field and garden crops to be fed to poultry. Buckwheat as a crop for the orchard furnishes a useful poultry food. Corn and other grains, sunflowers, and alfalfa hay are among the possible crops for winter. Some succulent crops are especially needed for the

winter, and among those which may be raised are cabbages and mangel beets. Potatoes, turnips, and carrots are suitable food but are used in a more restricted way, usually the unmarketable culls.

References.—Farmers' Bulletins 22, 164, 278, 339, 424, 433, 485, and 537.

Home projects.—With two or more yards to be used in rotation have pupils raise crops for forage for the hens giving the hens the range of each yard in turn as the crops reach the proper stage.

Whenever it is possible, have the pupils plan to cultivate crops in fields or garden to provide feed for the poultry, especially succulent foods for winter use.

Correlations.—Have pupils draw maps or ground plans of their poultry yards and buildings. Have them study how to arrange for alternate yards or some system of furnishing green food. In arithmetic have them compute the average cost of raising crops for poultry and decide which they can afford to raise in view of the local prices paid for feed.

It is profitable for a pupil to take up some study and projects in plant production which may be correlated with the animal project. Corn clubs or alfalfa-club work may be suitable.

LESSON THIRTEEN.

SUBJECT: SUMMER MANAGEMENT OF POULTRY.

MAY OR JUNE.

Topics for study.—(Omit such topics as have no local bearing.) Summer range. Shade and shelter. Constant supply of green food. Infertile eggs after hatching season. Keep chickens growing fast. Dispose of surplus cockerels as early as possible. Look up market for broilers. Continue preserving eggs while price remains low. Cleanse and sterilize drinking fountains frequently. Watch for evidence of vermin and diseases.

References.—Farmers' Bulletins 287, 355, 528, 530, 562, 594, 624, and 682. State agricultural college bulletins and club literature, also textbook chapters on summer management should be used and should be available to the pupils during the summer.

Home projects.—The teacher should have personal conferences with the pupils on the matter of summer poultry management.

Have each pupil plan to carry out in the vacation months those practices in relation to feeding, care, marketing, etc., which best fit his circumstances. Summer supervision is a serious problem. Club leaders in cooperation with the State agent in charge of such work often solve this problem. A teacher retained for summer months supervises such work in some communities. Committees of parent-teacher associations or granges often assist. Wherever parents will

agree to supervise the summer work, they are in a position to do it thoroughly.

Correlations.—Each pupil should complete as far as possible the report of his poultry project before the school term closes and should state his plan for the summer. This report may be made a language lesson. The accounts for cost of feed, labor, egg sales, etc., should be closed up to date and profit computed. These problems may well be taken up in the arithmetic classes. Have pupils write requests for such bulletins as they need at home in connection with their projects. Add to the survey charts any information obtained as to spring and summer practice, also any improvements.

SUPPLEMENT.

A DISTRICT POULTRY SURVEY.

[Sample forms.]

..... District. Date—September, 1916.

| Name of farmer. | Variety of poultry kept. | Total number. | Mature hens. | Mature males. | Intended for— | | To winter— | | |
|-----------------|--------------------------|---------------|--------------|---------------|---------------|--------|------------|----------|--------|
| | | | | | Market. | Table. | Old. | Pullets. | Males. |
| C. Adams..... | Rhode Island Reds | 125 | 25 | 3 | 16 | 15 | 20 | 70 | 4 |
| R. Davis..... | Scrubs..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Etc..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Total..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |

POULTRY CENSUS.

Date—September, 1916.

| | Breed. | Number. | Breed. | Number. | Breed. | Number. | Total. |
|------------------|-----------------|---------|----------------|---------|-----------------|---------|--------|
| Egg breeds..... | White Leghorns. | 275 | Brown Leghorns | 60 | Black Minorca.. | 25 | 360 |
| Meat breeds..... | Light Brahmas.. | 74 | ..... | ..... | ..... | ..... | ..... |
| Dual breeds..... | Barred Rocks... | 183 | ..... | ..... | ..... | ..... | ..... |
| Total..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |

POULTRY HOUSE AND MANAGEMENT SURVEY.

Date—October, 1916.

| Name of farmer. | Type of house. | Style of roof. | Style of front. | Fowls per pen. | Number housed. | Area per hen. | Type of floor. | Litter. | Nests. | Yards. |
|-----------------|----------------|----------------|-----------------|----------------|----------------|---------------|----------------|------------|--------|------------|
| C. Adams... | 2-colony. | Shed.. | Open.. | 16-25 | 125 | 6 feet.. | Gravel. | Straw..... | ..... | Alternate. |
| R. Davis..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Etc..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Total..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |

POULTRY-FEEDING PRACTICE.

[Survey form.]

Date—December, 1916.

| Name of farmer. | Dry mash used. | Scratch feed. | Green feed. | Other feed. |
|---------------------------|--|--|--|---|
| C. Adams, Hill Road... | Bran, 60 pounds ..
Corn meal, 30
pounds. ¹
Meat scraps, 9
pounds.
Salt, 1 pound..... | Oats, 1 bushel ¹ ...
Wheat, 1 bushel...

Cracked corn, 1
bushel. ¹
Buckwheat, $\frac{1}{2}$
bushel. ¹ | Alfalfa hay ¹
Mangels ¹

Cabbages ¹
Sprouted oats ¹ | Sunflower seeds. ¹
Oyster shells.

Grit.
Charcoal. |
| R. Davis, Maple Farm..... | ..... | ..... | ..... | ..... |
| | | | | |
| | | | | |

¹ Home grown.

CHICKEN RAISING.

[Survey form.]

Date—February to May, 1916.

| Name of farmer. | Source of eggs. | Date of setting. | Method of incubation. | Total hatched. | Method of brooding. | Comment. |
|-----------------|---|---------------------|---------------------------------------|----------------|-------------------------|-----------------------|
| C. Adams... | $\frac{3}{4}$ home, $\frac{1}{4}$ bought. | Feb. 10 to Mar. 20. | Two 200 egg water incubators; 5 hens. | 1,70 | Acme brooders and hens. | Raises some broilers. |
| | | | | | | |
| | | | | | | |
| | | | | | | |

PUPIL'S MONTHLY SUMMARY OF LAYING FLOCK.

| | |
|---|---------|
| Total No. eggs for month, | |
| Eggs sold..... Prices..... Total..... | \$..... |
| Eggs sold for setting..... at..... Total..... | |
| Eggs used at home..... Valued at..... | |
| Fowls sold..... | |
| Fowls eaten at home..... Valued at..... | |
| Total income for month..... | |
| Average number of hens..... | |
| Average eggs per hen..... | |
| Average eggs per day..... | |
| Average income per hen..... | |
| Cost of purchased feed used in month..... | \$..... |
| Value of home-grown feed used..... | |
| Estimate of kitchen scraps (not charged)..... | \$..... |
| Total value of feed for month..... | |
| Gross profit of income over feed..... | |
| Labor..... hours at..... Total..... | |
| Other charges or losses, from daybook..... | |
| Total charges..... | |
| Net profit over all charges..... | |
| Feed per hen, \$..... Total cost per hen..... | |
| Gross profit per hen, \$..... Net profit per hen..... | |

A SPECIMEN MONTHLY ACCOUNT.¹

DR.

| Date. | Item. | Feed. | Equip-ment. | Labor. | Miscel-laneous. | Total. |
|--------|--------------------------------|--------|-------------|--------|-----------------|--------|
| 1910. | | | | | | |
| Apr. 1 | 100 pounds beef scrap..... | \$3.00 | | | | \$3.00 |
| 5 | 4 bushels shelled corn..... | 3.00 | | | | 3.00 |
| 5 | 5 bushels oats..... | 3.25 | | | | 3.25 |
| 8 | Carpenter work on brooder..... | | | \$2.00 | | 2.00 |
| 8 | Lumber..... | | | | \$4.00 | 4.00 |
| 10 | 1 indoor brooder..... | | \$8.00 | | | 8.00 |
| 10 | 6 gallons kerosene..... | | | | .72 | .72 |
| 19 | 300 eggs for hatching..... | | | | 5.75 | 5.75 |
| 20 | 100 pounds oyster shell..... | .80 | | | | .80 |
| 25 | 3 bushels wheat..... | 3.75 | | | | 3.75 |
| | Total..... | 13.80 | 8.00 | 2.00 | 10.47 | 34.27 |

¹ From Bureau of Animal Industry Circ. 176, A System of Poultry Accounting, p. 4

A SPECIMEN MONTHLY ACCOUNT—Continued.

CR.

| Date. | Item. | Market
eggs. | Hatching
eggs. | Market
poultry. | Breeding
stock. | Total. |
|--------|---|-----------------|-------------------|--------------------|--------------------|--------|
| 1910. | | | | | | |
| Apr. 4 | 10 dozen eggs, at 24 cents..... | \$2.40 | | | | \$2.40 |
| 10 | 1 pen breeding fowls..... | | | | \$5.00 | 5.00 |
| 12 | 18 dozen eggs, at 24 cents..... | 4.32 | | | | 4.32 |
| 13 | 1 hen (home use)..... | | | \$0.55 | | .55 |
| 14 | 3 market hens..... | | | 1.80 | | 1.80 |
| 15 | 8 dozen eggs (home use), at 24 cents..... | 1.92 | | | | 1.92 |
| 17 | 15 dozen eggs, at 23 cents..... | 3.45 | | | | 3.45 |
| 19 | 7 dozen eggs (home use), at 23 cents..... | 1.61 | | | | 1.61 |
| 19 | 300 eggs, hatching (home use)..... | | \$5.75 | | | 5.75 |
| 20 | 50 day-old chicks..... | | | | 3.00 | 3.00 |
| 23 | 7 dozen eggs (home use), at 23 cents..... | 1.61 | | | | 1.61 |
| 29 | 100 eggs, hatching..... | | 3.00 | | | 3.00 |
| 30 | 6 dozen eggs, at 22 cents..... | 1.32 | | | | 1.32 |
| | Total..... | 16.63 | 8.75 | 2.35 | 8.00 | 35.73 |

A BALANCE SHEET.¹

[Yearly or more frequently.]

| | Debit. | Credit. | Balance. |
|---|----------|----------|----------|
| Value of inventory January 1, 1910..... | \$347.30 | | |
| Interest at 6 per cent on capital invested, as represented by value of inventory above..... | 20.84 | | |
| Expenditures during 1910..... | 273.70 | | |
| Value of inventory January 1, 1911..... | | \$431.40 | |
| Receipts during 1910..... | | 368.77 | |
| Total..... | 641.84 | 800.17 | |
| Balance (profit)..... | | | \$158.33 |

¹ From Bureau of Animal Industry Circ. 176, p. 6

AN ALTERNATE-YARD CROPPING PLAN.

One of the suggested crops is to be grown in one yard while a crop is pastured in the alternate yard.

| | Yard 1. | Single flock house. | Yard 2. |
|-----------------------|---|---------------------|--|
| April to July. | <i>Growing.</i>
Oats.
Chard or lettuce.
Clover or vetch.
Sunflowers (shade and seed).
Cow peas.
Rape. | | <i>Feeding.</i>
Winter rye.
Winter vetch.
Crimson clover (New Jersey and South).
Sweet clover. |
| July 1 to October 1. | <i>Feeding.</i>
Oats.
Chard and lettuce.
Clover or vetch.
Cow peas.
Rape. | | <i>Growing.</i>
Buckwheat.
Dwarf Essex rape.
Flat turnips. |
| October 1 to April 1. | <i>Growing.</i>
Oats.
Winter rye.
Winter vetch.
Sweet clover.
Crimson clover. | | <i>Feeding.</i>
Buckwheat.
Dwarf Essex rape.
Flat turnips.
Soy beans. |

Select crops which will grow well in the given district.

Thickly sown crops for succulent food and summer shade. Adapted to climate of medium latitudes. Dates must be modified for extreme north or south. Consult local extension agents.

FRONT AND BACK ALTERNATE YARD PLAN.

1. Back yard. Permanent.
Blue grass and clover or blue grass and alfalfa in sod.
To be used as range while crops are growing in the front yard. Large area desirable.

Pen in continuous style house.

2. Front yard. Temporary crops.
November 1 to April 1. Feed winter rye, vetch, crimson clover, etc.
April 1 to July 1. Grow rape, chard, lettuce, buckwheat.
July and August. Feed.
September 1 to November 1. Grow winter rye, vetch, crimson clover, etc.

A ROTATION FOR POULTRY YARDS WHICH HAS PROVED PRACTICAL IN SOME LOCATIONS.

| Date. | Yard A. | Yard B. |
|--------------------------|-------------------------|----------------------|
| Mar. 1 to Apr. 30..... | Peas and oats..... | Feeding. |
| Apr. 30 to May 25..... | Feeding..... | Peas and barley. |
| May 25 to June 15..... | Dwarf Essex rape..... | Feeding. |
| June 15 to July 10..... | Feeding..... | Buckwheat and oats. |
| July 10 to Aug. 1..... | Buckwheat..... | Feeding. |
| Aug. 1 to Aug. 20..... | Feeding..... | Cow peas and millet. |
| Aug. 20 to Sept. 20..... | Rye, vetch, clover..... | Feeding. |
| Sept. 20 to Dec. 1..... | Feeding..... | Rye and vetch. |

Special care must be taken lest the fowls return to the yard to which they have become accustomed.

GRAZING CROPS FOR POULTRY.¹

[Adapted to the latitude of the southern boundary of Pennsylvania.]

| Crop. | When sown. | Seed per acre. | Grazing period. | |
|--------------------------------------|------------------------|---------------------------------|--------------------------------|------------------------------|
| | | | Stage. | Duration. |
| Peas and oats..... | About Apr. 15..... | 1 bushel peas, 2 bushels oats. | About May 20..... | Until full grown. |
| Chard..... | May 10 to July 1.... | 3 pounds..... | 8 inches-10 inches high. | Until consumed. |
| Rape..... | Beginning Apr. 20.... | 6 pounds..... | 6 inches-8 inches high. | Do. |
| Red clover..... | Aug. 20..... | 12 pounds..... | About May 15..... | Until fed down closely. |
| Turnips..... | do..... | 3 pounds..... | Sept. 20..... | Until snow falls. |
| Buckwheat..... | May 10 to July 1.... | 1 bushel..... | 6 weeks..... | Until mature. |
| Soy beans..... | May 10 to June 10.... | do..... | 12 inches-15 inches high. | |
| Rye ² and crimson clover. | Sept. 1..... | 1 bushel rye, 15 pounds clover. | Graze early winter and spring. | |
| Sweet clover..... | Aug. 15 to Sept. 1.... | 25 pounds..... | 8 inches-10 inches high. | Until fed down or too tough. |
| Alfalfa..... | August..... | 20 pounds..... | do..... | Alternate periods. |

¹ Suggestions by the Division of Forage Crop Investigations of the Bureau of Plant Industry. This phase of the investigations has received little attention from the viewpoint of poultry grazing, especially as to the relation of number of fowls to area of crops.

² Winter wheat may be substituted for rye. Farther north substitute hairy vetch for crimson clover.

MANAGEMENT OF POULTRY MANURE.

The manure produced is a valuable by-product of poultry raising. It is estimated that the average night droppings of a hen amount to 30 to 40 pounds per year. This represents the manure which can certainly be saved with the exercise of a little care. A conservative estimate indicates that this manure contains fertilizing constituents which would cost 20 to 25 cents if bought in the form of commercial fertilizers at ordinary prices. A flock of 100 hens would at this rate produce manure worth \$20 to \$25 per year. If, however, the manure is not properly cared for, as much as one-half of its fertilizing value is likely to be lost. To prevent loss frequent cleaning of the dropping boards is necessary, and some sort of absorbent should be used daily. The use in moderate quantities of fine, dry loam or road dust, or, preferably, mixtures of these with such materials as land plaster, acid phosphate, and potash salts has been recommended. Sawdust has also been used with good results at the rate of 10 pounds per hen per year mixed with 16 pounds of acid phosphate and 8 pounds of kainit. This gives a fertilizer which contains about 0.25 per cent of nitrogen, 4.5 per cent of phosphoric acid, and 2 per cent of potash, and is worth about \$10 per ton at ordinary prices of these fertilizing constituents. It is a better balanced fertilizer than manure alone and is usually in better mechanical condition for application to the soil by means of fertilizer distributors or manure spreaders.

With the present high price of potash salts it is impracticable to use such materials in the way suggested, and it may also be impracticable to use acid phosphate. In this case somewhat larger amounts of sawdust should be used.

Sifted coal ashes may be used as an absorbent, but wood ashes or lime should not be mixed with the manure, as they are likely to cause the loss of its most valuable fertilizing constituent, namely, nitrogen (ammonia). Occasionally the litter from the poultry house may be mixed with the manure. This increases the bulk, but greatly reduces the value per pound of the manure and makes it difficult to apply to the soil, except where it is to be broadcasted and plowed in.

Poultry manure is more valuable than the manure of any other common farm animal, as the following table shows:

Analyses and value per ton of manure of different animals.

| Animal. | Nitrogen. | Phosphoric acid. | Potash. | Value per ton. |
|--------------|------------------|------------------|------------------|----------------|
| | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | |
| Poultry..... | 0.80 to 2.000 | 0.50 to 2.000 | 0.80 to 0.900 | \$7.07 |
| Sheep..... | .768 | .391 | .591 | 3.30 |
| Hogs..... | .840 | .390 | .320 | 3.29 |
| Horses..... | .490 | .260 | .480 | 2.21 |
| Cattle..... | .426 | .290 | .440 | 3.02 |

Poultry manure is particularly well adapted to gardening, and the pupils should either use it on their own garden projects or dispose of it at a good price, thus increasing the profits of their flocks.

POULTRY-CLUB REPORT FORMS.

[Furnished by the Bureau of Animal Industry, U. S. Department of Agriculture.]

These or similar forms are used by the club leaders of the different States and may be obtained through the State club leader of boys' and girls' clubs at the State college of agriculture.

REPORT OF HATCHING CHICKS.

Name..... Age.....
 Post office..... County..... State.....
 Name of poultry club..... Year.....

| Lot. | Number of eggs. | Kind of eggs. | Date set. | Hen or incubator. | Eggs tested out. | | | | Eggs remaining. | Chicks hatched. |
|--------|-----------------|---------------|-----------|-------------------|------------------|-------|--------------------|-------|-----------------|-----------------|
| | | | | | On seventh day. | | On fourteenth day. | | | |
| | | | | | Infertile. | Dead. | Infertile. | Dead. | | |
| 1..... | | | | | | | | | | |
| 2..... | | | | | | | | | | |
| Etc.. | | | | | | | | | | |

REMARKS.—If an incubator is used, state make of same and total amount of the kerosene consumed. Make of incubator,; kerosene used, gallons.

State the total number of hours of labor spent in attending hens or incubator: hours.

Two copies of this report must be filled out, one to be given to the teacher at the end of the weaning period of the last lot of chicks and the other to be retained by the club member. (This is to be done for all reports at the time they are filled out.)

REPORT OF BROODING CHICKS.

Name..... Age.....
 Post office..... County..... State.....
 Name of poultry club..... Year.....

| Lot. | Number of chicks. | Kind of chicks. | Date hatched. | With hen or brooder. | Date chicks were weaned. | Number of chicks died. | Number of chicks remaining. | Weight of lot when weaned. | |
|----------|-------------------|-----------------|---------------|----------------------|--------------------------|------------------------|-----------------------------|----------------------------|---------|
| | | | | | | | | Pounds. | Ounces. |
| 1..... | | | | | | | | | |
| 2..... | | | | | | | | | |
| Etc..... | | | | | | | | | |

REMARKS.—If a brooder is used, state make of same (or homemade) and total amount of oil consumed. Make of brooder.....
 Kerosene used gallons. State the total number of hours spent in attending hens and chicks or brooder hours. State the kinds of feed and value of each.

| Kind of feed. | Number of pounds used. | Cost of feed. | |
|---------------|------------------------|---------------|--------|
| | | Dollars. | Cents. |
| | | | |
| | | | |
| | | | |
| | | | |

REARING REPORT FROM WEANING TIME UNTIL JANUARY 1.

Name..... Age.....
 Post office..... County..... State.....
 Name of poultry club..... Year.....

| Number of chicks at weaning time. | Kind of chicks | Chickens sold for market. | | Total amount received. | Pullets raised to Jan. 1. | Cockerels raised to Jan. 1. | Number of chicks died. | Number of chicks remaining. | Total weight Jan. 1. |
|-----------------------------------|----------------|---------------------------|---------|------------------------|---------------------------|-----------------------------|------------------------|-----------------------------|----------------------|
| | | Number. | Pounds. | | | | | | Pounds. |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

REMARKS.—Chickens sold for breeders: Cockerels—Number, value \$.....; pullets—Number, value \$.....

Highest price received for a single bird: \$.....; cockerel or pullet

Exhibited at fair. Number of birds exhibited; total prize money received, \$.....

Number of special premiums; nature of same

Chickens used at home should be credited at market prices.

Labor at 10 cents per hour: Number of hours; cost \$.....

| Kind of feed. | Number of pounds used. | Cost of feed. | |
|---------------|------------------------|---------------|--------|
| | | Dollars. | Cents. |
| | | | |
| | | | |
| | | | |
| | | | |

YEARLY REPORT.

Name..... Age.....
 Post office..... County..... State.....
 Name of poultry club..... Year.....

DR.

| Month. | Cost of feed. | Cost of equipment. | Labor. | Cost of eggs for hatching. | Cost of breeding stock. | Number of hens died. | Miscellaneous. |
|---------------|---------------|--------------------|--------|----------------------------|-------------------------|----------------------|----------------|
| January..... | | | | | | | |
| February..... | | | | | | | |
| Etc..... | | | | | | | |

CR.

| Month. | Market eggs sold. | | Hatching eggs sold. | | Market poultry sold. | | Breeding stock sold, value. | Miscellaneous. |
|---------------|-------------------|--------|---------------------|--------|----------------------|--------|-----------------------------|----------------|
| | Dozen. | Value. | Sittings. | Value. | Pounds. | Value. | | |
| January..... | | | | | | | | |
| February..... | | | | | | | | |
| Etc..... | | | | | | | | |

INVENTORY REPORT.

Name..... Age.....
 Post office..... County..... State.....
 Name of poultry club..... Year.....

Inventory January 1.

Stock: Number of cocks, value, \$.....; number of hens, value, \$.....; number of pullets,, value, \$.....; number of cockerels,, value, \$..... Total value of stock, \$.....

Equipment: Value of poultry houses, \$.....; value of feed hoppers, \$.....; value of drinking vessels, \$.....; value of brood coops, \$.....; value of poultry fences, \$.....; number of incubators,, make,, value, \$.....; number of brooders,, make, value, \$.....; value of grain on hand, \$..... Total value of equipment, \$.....

LIST OF PUBLICATIONS RELATED TO THE SUBJECT.

FARMERS' BULLETINS AVAILABLE AT THE DATE OF THIS PUBLICATION.

- 22. The Feeding of Farm Animals.
- 51. Standard Varieties of Chickens.
- 142. Principles of Nutrition.
- 182. Poultry as Food.
- 287. Poultry Management.
- 355. A Successful Poultry and Dairy Farm.
- 445. Marketing Eggs Through the Creamery.
- 452. Capons and Caponizing.
- 480. Practical Methods of Disinfecting Stables.
- 493. The English Sparrow as a Pest.
- 511. Farm Bookkeeping.
- 528. Hints to Poultry Raisers.
- 530. Important Poultry Diseases.
- 562. The Organization of Boys' and Girls' Poultry Clubs.
- 574. Poultry House Construction.
- 585. Natural and Artificial Incubation of Hens' Eggs.
- 594. Shipping Eggs by Parcel Post.
- 624. Natural and Artificial Brooding of Chickens.
- 635. What the Farm Contributes Directly to the Farmer's Living.
- 656. The Community Egg Circle.
- 682. A Simple Trap Nest for Poultry.

SPECIAL LINES OF FOWLS.

- 200. Turkeys.
- 234. The Guinea Fowl.¹
- 684. Squab Raising.
- 697. Duck Raising.

SCHOOL METHODS.

- 586. Collection and Preservation of Plant Material for Use in the Study of Agriculture.
- 606. Collection and Preservation of Insects and Other Material for Use in the Study of Agriculture.
- Department of Agriculture Bulletin No. 132, Correlating Agriculture With the Public School Subjects in the Southern States.¹
- Department of Agriculture Bulletin No. 281, Correlating Agriculture With the Public School Subjects in the Northern States.
- Department of Agriculture Bulletin No. 385, School Credit for Home Practice in Agriculture.

FARMERS' BULLETINS ON FEEDING AND CROPS FOR FEEDING.

- 22. The Feeding of Farm Animals.¹
- 142. Principles of Nutrition and the Nutritive Value of Food.¹
- 164. Rape as a Forage Crop.¹
- 278. Leguminous Crops.¹
- 318. Cowpeas.
- 339. Alfalfa.

¹Available at 5 cents a copy; sold by the Superintendent of Documents.

- 424. Oats: Growing the Crop.
- 433. Cabbage.
- 443. Barley: Growing the Crop.
- 485. Sweet Clover.
- 537. How to Grow an Acre of Corn.
- 552. Kafir as a Grain Crop.
- 617. School Lessons on Corn.
- 686. Uses of Grain Sorghums.

The Yearbook of the Department of Agriculture has articles of value, some of which are published as separates and are sold by the Superintendent of Documents.

The Prevention and Treatment of Diseases in Poultry, 1911 Yearbook, pp. 177-192; also issued as Separate No. 559; price, 5 cents.

The Handling and Marketing of Eggs, 1911 Yearbook, pp. 467, 468; as Separate No. 584; price, 5 cents. This is an abstract of Bureau of Animal Industry Bul. No. 141, The Improvement of the Farm Egg.

Improving the Quality of Poultry and Eggs, 1912 Yearbook, pp. 345-352; as Separate No. 596; price, 5 cents.

Handling Dressed Poultry a Thousand Miles from Market, 1912 Yearbook, pp. 285-292; as Separate No. 591; price, 15 cents.

Effect of the Present Method of Handling Eggs, 1910 Yearbook, pp. 461-476.

Bureau of Entomology Circular No. 92, Mites and Lice on Poultry; price, 5 cents.

Bureau of Entomology Circular No. 170, The Fowl Tick; price, 5 cents.

Yearbooks are usually to be found in local libraries or in the homes of some of the farmers.

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BULLETIN No. 465

Contribution from the Bureau of Biological Survey
E. W. NELSON, Chief



Washington, D. C.



February 23, 1917

PROPAGATION OF WILD-DUCK FOODS.

By W. L. McATEE, *Assistant Biologist.*

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INTRODUCTION.

Information concerning the propagation of valuable wild-duck foods is constantly requested by State game commissions, game protective associations, and sportsmen's clubs, and by individuals interested in the protection, preservation, and propagation of waterfowl. The Biological Survey has endeavored to meet the demand by issuing three publications¹ on the more important food plants of wild ducks, by correspondence relating to local problems, and in certain cases by special examination and report. The bulletins thus far published have contained accounts of the value, nature, range, and methods of propagation of 19 groups of plants comprising more than 60 species.

The present bulletin is a revision of the first two of these publications and discusses the following plants suitable for wild-duck food: Wild rice, wild celery, pondweeds, arrowheads (especially delta

¹ Biol. Surv. Circ. No. 81, Sept. 9, 1911; and U. S. Dept. Agr. Bulls. No. 58, Feb. 7, 1914, and No. 205, May 20, 1915.

NOTE.—This bulletin is for general distribution among persons and organizations interested in the protection, preservation, and propagation of waterfowl. It supersedes Biological Survey Circular No. 81, dealing with wild rice, wild celery, and pondweeds; and Department Bulletin No. 58, dealing with delta potato, wapato, chufa, wild millet, and banana waterlily.

potato and wapato), chufa, wild millet, and waterlilies (especially the banana waterlily).¹ The kinds of foods that can be recommended for propagation must practically be restricted to those already on the market. This fact has controlled the selection of the varieties discussed in previous publications. It is highly desirable that dealers increase the scope of their stock so that persons interested may obtain seeds or other parts necessary for the propagation of additional kinds, a number of which are just as valuable as food for wild ducks as some now offered for sale. The best of these are shown in Table I.

TABLE I.—Wild-duck foods not at present on the market.

| No. | Common name. | Scientific name. | General range. | Local conditions. |
|-----|-----------------------------------|--------------------------------------|------------------------|----------------------------|
| 1 | Bur reed..... | <i>Sparganium eurycarpum</i> ... | United States..... | Marshes. |
| 2 | Do..... | <i>Sparganium angustifolium</i> ... | Northern States..... | Quiet water. ² |
| 3 | Pondweed..... | <i>Potamogeton heterophyllus</i> ... | Northern Hemisphere. | Do. |
| 4 | Do..... | <i>Potamogeton pusillus</i> | do..... | Do. |
| 5 | Do..... | <i>Potamogeton filiformis</i> | Northern States..... | Do. |
| 6 | Do..... | <i>Potamogeton interior</i> | Western States..... | Do. |
| 7 | Western widgeon-grass | <i>Ruppia occidentalis</i> | do..... | Saline lakes. |
| 8 | Horned pondweed.... | <i>Zannichellia palustris</i> | Cosmopolitan..... | Fresh or brackish water. |
| 9 | Bushy pondweed..... | <i>Najas flexilis</i> | Northern Hemisphere. | Quiet water. |
| 10 | Arrowhead..... | <i>Sagittaria longiloba</i> | Western States..... | Shallow water. |
| 11 | Do..... | <i>Sagittaria rigida</i> | Northern States..... | Do. |
| 12 | Do..... | <i>Sagittaria teres</i> | Atlantic coast..... | Do. |
| 13 | Do..... | <i>Sagittaria graminea</i> | Eastern States..... | Do. |
| 14 | Do..... | <i>Sagittaria papillosa</i> | Gulf States..... | Do. |
| 15 | Grass..... | <i>Panicum condensum</i> | Eastern States..... | Swamps. |
| 16 | Switch grass..... | <i>Panicum virgatum</i> | United States..... | Wet soil. |
| 17 | Salt-marsh grass..... | <i>Spartina cynosuroides</i> | Atlantic coast..... | Salt marshes. |
| 18 | Cord grass..... | <i>Spartina michauxiana</i> | Eastern States..... | Fresh or brackish marshes. |
| 19 | Do..... | <i>Spartina gracilis</i> | Western States..... | Saline soil. |
| 20 | Meadow grass..... | <i>Panicularia nervata</i> | United States..... | Wet soil. |
| 21 | Bulrush..... | <i>Scirpus americanus</i> | Cosmopolitan..... | Fresh or brackish marshes. |
| 22 | Do..... | <i>Scirpus validus</i> | North America..... | Shallow water. |
| 23 | Do..... | <i>Scirpus occidentalis</i> | United States..... | Do. |
| 24 | Do..... | <i>Scirpus paludosus</i> | do..... | Salt marshes. |
| 25 | Do..... | <i>Scirpus robustus</i> | Atlantic coast..... | Do. |
| 26 | Do..... | <i>Scirpus fluviatilis</i> | Northern States..... | Shallow water. |
| 27 | Do..... | <i>Scirpus cubensis</i> | Gulf States..... | Swamps. |
| 28 | Saw grass..... | <i>Cladium effusum</i> | Southeastern States... | Coast marshes. |
| 29 | Sedge..... | <i>Carex decomposita</i> | Eastern States..... | Swamps. |
| 30 | Wampee ³ | <i>Peltandra virginica</i> | do..... | Shallow water. |
| 31 | Pickereel weed ³ | <i>Pouteria cordata</i> | do..... | Do. |

¹ Other plants are included in Department Bulletin No. 205 (25 p., 23 figs.), as follows: Musk grass, duckweeds, frogbit, thalia, water elm, swamp privet, eelgrass, widgeon-grass, watercress, waterweed, and coontail.

² Where not specified, fresh water is to be understood.

³ This plant now on sale by some dealers.

TABLE I.—Wild-duck foods not at present on the market—Continued.

| No. | Common name. | Scientific name. | General range. | Local conditions. |
|-----|----------------------|------------------------------------|------------------------|-------------------------------|
| 32 | Smartweed..... | <i>Polygonum amphibium</i> | United States..... | Shallow water. |
| 33 | Do..... | <i>Polygonum pennsylvanicum</i> . | do..... | Wet soil. |
| 34 | Do..... | <i>Polygonum opelousanum</i> .. | Eastern States..... | Do. |
| 35 | Do..... | <i>Polygonum hydropiperoides</i> . | United States..... | Do. |
| 36 | Do..... | <i>Polygonum hydropiper</i> | Northern Hemisphere. | Do. |
| 37 | Do..... | <i>Polygonum punctatum</i> | North America..... | Do. |
| 38 | Do..... | <i>Polygonum sagittatum</i> | United States..... | Do. |
| 39 | Saltwort..... | <i>Salicornia europæa</i> | Northern Hemisphere. | Salt marshes and sea beaches. |
| 40 | Do..... | <i>Salicornia ambigua</i> | Both coasts..... | Do. |
| 41 | Water primrose..... | <i>Jussiaea leptocarpa</i> | Southeastern States... | Swamps. |
| 42 | Water pennywort..... | <i>Hydrocotyle umbellata</i> ... | United States..... | Do. |

Were all these plants available to persons interested in improving the food supply of wild ducks the outlook would be most satisfactory, for from these and the plants hitherto listed and described something of value could be selected for almost any environmental condition.

Classifying the plants recommended for propagation according to the conditions to which they are suited, we have as a salt-water plant, eelgrass; for brackish water, widgeon-grass, sago pondweed, and wild celery, all of which also grow in fresh water, the last two abundantly; for fresh water with slight current, wild rice, wild celery, all the pondweeds, and watercress; for fresh water that is quiet except for wind currents, pondweeds, banana waterlily, musk grasses, waterweed, and coontail; for the border line between water and marsh or for shallow fresh water, delta potato, wapato, wild millet, frogbit, and thalia; for small openings in marshes or other absolutely quiet waters, duckweeds; for the margin of fresh water where there is no marsh, wild millet; for land dry in summer and overflowed in winter, chufa and wild millet; for bodies of fresh water, almost always full but sometimes drying up in summer, in shallow places wapato and delta potato, and in deeper water, the tuberous white waterlily; and for swamps, swamp privet and water elm.

A recent study of the vegetation of the lakes of the Nebraska sand-hill region discloses the important fact that widgeon-grass and sago pondweed withstand alkaline conditions better than any other plants. It is probable that wild celery also will be found to have a degree of endurance of alkalinity.

Some of the new plants listed in Table I are especially desirable, because they are suitable for certain situations besides those inhabited by the plants mentioned in the last two paragraphs. They include

six for salt marshes (namely, Nos. 17, 18, 21, 24, 25, and 28), two for salt marshes and sea beaches (39, 40), one for saline lakes (7), two for fresh or brackish marshes (18, 21), one for fresh or brackish water (8), and eight for wet soil (16, 20, and 33 to 38); there are also five for swamps (15, 27, 29, 41, 42) in the number.

WILD RICE.

VALUE AS DUCK FOOD.

Wild rice (*Zizania palustris* and *Z. aquatica*) in every stage of its growth is eaten by one or another of the North American ducks and geese, and practically all of them feed on its ripened grain. It is the staple fall food of many ducks in the numerous rice marshes of eastern United States. The seeds are obtained mainly from the bottom in shallow water, where they have fallen into a bed of soft muck to await germination. Germination is often so delayed that grain may sprout at any time up to at least 18 months after ripening. This accounts for the fact that young shoots and germinating seeds of wild rice are found in ducks' stomachs at practically all seasons. The shoots are devoured by many species, the flowers have been found in the wood duck's stomach, and the stems and leaves of the mature plants are eaten by geese. Wild rice constituted more than 17 per cent of the food of 209 mallards examined, 12 per cent of that of 51 black ducks, and over 11 per cent of that of 75 wood ducks. Other species known to feed upon the plant are the Canada goose, snow goose, pintail, widgeon, lesser and greater scaups or bluebills, canvas-back, redhead, green-winged and blue-winged teals, buffle-head, and ruddy duck.

DESCRIPTION OF PLANT.

Wild rice is a tall, round-stemmed grass with long, flat, pointed leaves (fig. 1). The stem, which may be as much as 2 inches in diameter, is hollow, but is furnished with transverse partitions between as well as at the joints. These partitions may be seen when the stem is cut lengthwise. The base of the stem is in the form of a stout hook, and from it arise the numerous fibrous roots which serve mainly to anchor the plant to the bottom. The flowers of wild rice usually appear during the latter part of July, but may be found as late as November. The appearance of the flower head is very characteristic (fig. 1); the lower branches, which bear the staminate or male flowers, are widely separated and stand out from the stem, while the upper branches of pistillate flowers are erect and more



FIG. 1.—Wild rice in flower. (One-half natural size.)

compactly grouped. The grain (fig. 2, A) of wild rice is from one-half to three-fourths of an inch in length, slender, of uniform diameter, and with rounded or pointed ends. A low rib runs along the whole length of one side and a shallow groove along the other. The husk of the seed (fig. 2, B) has six longitudinal grooves and a long, pointed beak, the whole being an inch and a half or sometimes even more in length. The appearance of the flower head or of the

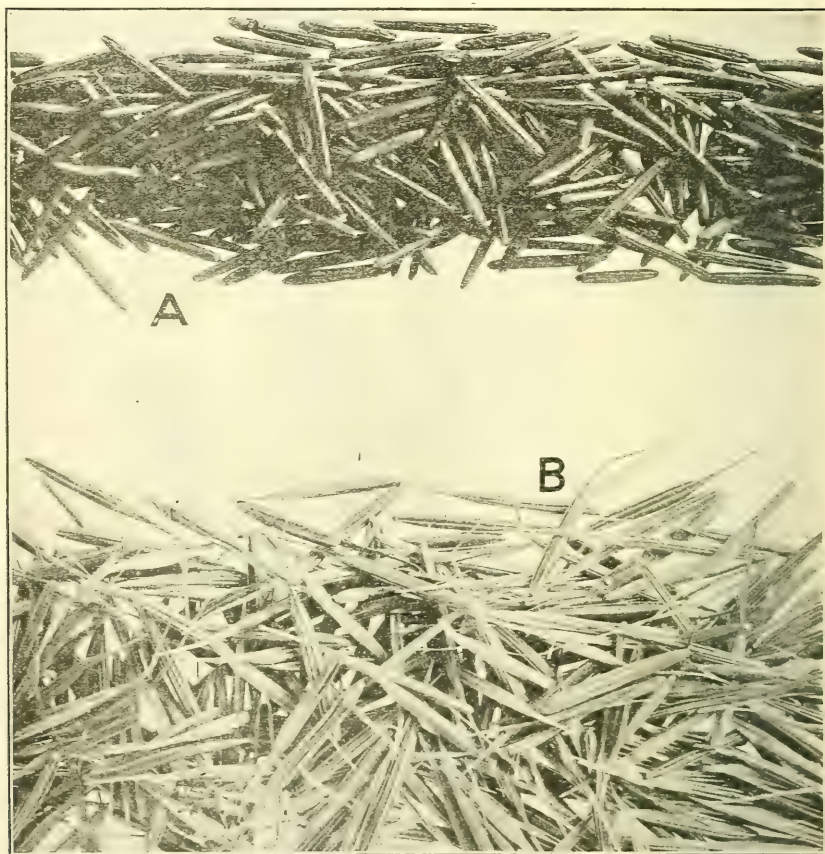


FIG. 2.—Wild rice seed: (A) With the hull off and (B) with the hull on. (From Bull. 50, Bureau of Plant Industry.)

grain distinguishes wild rice from any other aquatic grass in its range.¹

DISTRIBUTION.

Natural growths of wild rice have been found from the northern end of Lake Winnipeg eastward along the northern shores of the

¹ The southern white marsh or folle avoine (*Zizaniopsis*), superficially much like *Zizania*, does not have the flower head as a whole divided into pistillate and staminate parts, and the grain is ovoid and without a long beak.

Great Lakes and the St. Lawrence River to New Brunswick;¹ from the central Dakotas, western Nebraska, and eastern Texas to the Atlantic coast; and as far south along that coast as central Florida (fig. 3). The plant is rather local and of course is confined to the lowlands. The center of its abundance is in Wisconsin, Iowa, and Minnesota.

PROPAGATION.

Although wild rice does not grow naturally in every suitable place within its range, in most cases it can be made to do so by transplanting. Formerly wild rice was often transplanted by various

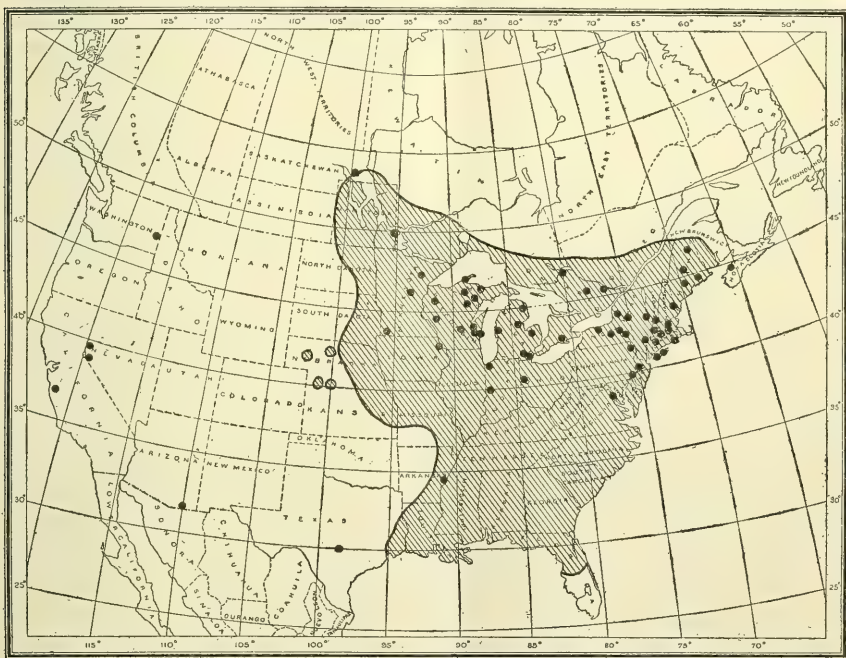


FIG. 3.—Range of wild rice. (Black spots show where it has been successfully transplanted.)

tribes of Indians, and investigations by the Bureau of Plant Industry have shown that with proper treatment of the seed the plant may be propagated in any favorable waters in the country. It has also been successfully grown in Europe. The black spots on the accompanying map (fig. 3) represent numerous localities where it has been successfully transplanted in North America. The showing thus made should encourage those who are looking for a plant to make barren waters attractive to ducks, and especially those who have already tried wild rice without success. However, experimenters must be prepared for occasional failure, for the plant sometimes refuses to grow

¹ It is reported without definite locality from Newfoundland.

in localities which appear to possess every requisite for its successful propagation. The usual cause of failure has been improper treatment of the seed between the time of harvesting and sowing, resulting in loss of vitality. When growing naturally, the ripe seeds fall directly into the water, where they sink, and, being provided with barbed beaks, penetrate deeper and deeper into the muck surrounding the roots of the parent plant. There they lie through the winter. They may germinate in spring, or they may lie practically dormant through still another cold season. The seeds therefore remain wet until ready to sprout; they are exposed to currents of water, are not in close contact with each other, and are not subjected to very high temperatures. To succeed with wild rice it is necessary to imitate nature's methods. Keeping large quantities of the seed in close contact often causes fermentation, but this can be prevented by cold storage.

So far as propagation depends on the preservation of the vitality of the seed, the methods so carefully worked out by the Bureau of Plant Industry¹ insure success. Several seed firms handle wild rice properly and will deliver it in either spring or fall as desired. The grain is kept wet and in cold storage, and when shipped is packed in damp moss or fiber.

Sometimes when the stand of wild rice has become reduced it is advisable to prevent consumption by ducks by harvesting the grain and then sowing it after the spring migration. Because the seeds of wild rice ripen and drop off a few at a time, they must be collected every day or so, or the heads must be bunched and tied, so as to prevent the loss of seed. The grain may perhaps be allowed to stand a short time in cold water, if the water is changed daily. But when the whole crop has been gathered it should be placed at once in cold storage, at a temperature just above freezing (from 32° to 34° F.), but still exposed to the air in an open cask or vat.

In cold climates seed may sometimes be perfectly preserved by improvised methods. For instance, wild rice seed kept out of doors and covered with water which was changed daily during the winter, except when frozen, germinated very satisfactorily. It has been stored also in partly filled burlap bags, among which blocks of ice were placed, and the whole covered with sawdust and kept wet. Usually, however, where cold storage is not available it is better to buy seed from a reliable firm.

Where to plant.—Wild rice thrives best on a mud bottom, though it has been known to grow in sand. This may be underlain by various soils, but there should be a layer of mud from at least 2 to 4 inches deep, and preferably deeper. Wild rice usually does not do well

¹ Bull. 50, 1903; Bull. 90, Pt. I, 1905.

where there is much current or change in the level of the water, although it grows abundantly on tide flats. It is not adapted to entirely stagnant water.

It may also be added that the salt-water limits of wild rice may be determined approximately by the simple test of taste. When water is appreciably salty to the taste it is too salty for the successful growth of this plant.¹

From 4 inches to 6 feet of water are about the limits of its usual occurrence, and it does best in from 1 to 3 feet. In shallow water it may be killed by heat in summer, so it is best, in southern localities especially, to sow the seed in not less than 2 feet of water.

How to plant.—The least possible time must intervene between removal from cold storage and sowing. Broadcast sowing answers every purpose, and the seed should be thickly sown, as, when near together, the growing plants support each other, the root anchorage is protected, and a good stand is more likely to result than if the seed is more widely scattered.

When to plant.—Fall has usually been considered the most desirable time for sowing, but it has been proved that seed sown in spring will bring a full crop, and for several reasons spring sowing is usually advisable. Where seed has been sown in fall, the bottom may freeze and the seed be carried off by the ice in spring. Ducks and other waterfowl, as well as some fishes, eat the seed, and the less it is exposed to their depredations the more abundant will be the crop. Seed is likely also to be buried by depositions of mud, or swept away by currents, especially in freshets. These dangers may be avoided by sowing late enough in spring to avoid the worst spring freshets, but in time to get the benefit of the first good growing weather; that is, when the temperature of the water approaches 60° F.

WILD CELERY.

VALUE AS DUCK FOOD.

The names wild celery (*Vallisneria spiralis*) and canvas-back duck have been closely associated in the annals of American sport. To a certain extent this association is justified, since the canvas-back evidently is very fond of the subterranean propagating buds of this plant. However, the assertion that the flavor of the canvas-back is superior to that of any other duck and that this depends on a diet of wild celery is not proved, to say the least. The scaups, or bluebills, and the redhead also are very fond of wild celery, and are fully as capable of getting the delicious buds as is the canvas-back. Several other ducks get more or less of this food, the writer finding that even the scoters on a Wisconsin lake in fall lived almost exclusively on it

¹ Scofield, C. S., Bull. 72, Bureau of Plant Industry, Pt. II, p. 8. 1905.

for the time. All parts of the plant are eaten by ducks, but the tender winter buds (fig. 8) and rootstocks are relished most. Wild celery buds can usually be obtained only by the diving ducks, as the bluebills, redhead, canvas-back, and scoters. The nondiving species, as the mallard, black duck, baldpate, and the geese, get an occasional bud, but more often they feed upon the leaves. Wild fowl not thus far specifically mentioned which also feed upon wild celery include the wood ducks, pintail, ruddy duck, buffle-head, whistler, green-

winged and blue-winged teals, greater and lesser scaups or bluebills, white-winged and surf scoters, and whistling swan.

DESCRIPTION OF PLANT.

Wild celery (fig. 4) is a wholly submerged plant with long, flexible, ribbonlike leaves of light translucent green and of practically uniform width (anywhere from one-fourth to three-fourths of an inch) from root to tip. Of course the leaves are narrowed near the tip and may be somewhat serrate or wavy-margined there, but they are never ex-



FIG. 4.—Wild celery. (Reduced. From Reichenbach.)

panded and the venation is peculiar. A leaf held up to the light displays numerous fine straight parallel veins running the whole length. There are, besides, one median and two lateral prominent veins connected at intervals by irregular cross veinlets (see fig. 5). Wild celery may be distinguished from eelgrass (*Zostera marina*), which lives in brackish or salt water, by the fact that its leaves grow in bundles from the rootstocks, while those of eelgrass arise singly and alternate on opposite sides of the stem. The leaves of wild celery generally are more than a fourth of an inch wide, while those of eelgrass are about that width or narrower. Pipewort (*Eriocaulon*), a fresh-water plant,

often having ribbonlike leaves, may be recognized by the reticulation of the entire leaf into small cells by veins of nearly uniform size.

In certain stages some of the arrowheads (*Sagittaria*) are difficult to distinguish from wild celery, though they usually have the end of the leaf expanded into a proper leaf blade or else quite pointed, neither of which characteristics is to be found in *Vallisneria*. Investigation of the subterranean organs will decide the matter, however. For a description of those of *Sagittaria* see pages 25-26.

The flowers of wild celery, usually seen in July, are peculiar. The staminate flowers, at first attached at the base of the plants, later float on the surface of the water and fertilize the pistillate flower. The latter is attached to a long, slender, round stem, which contracts into a spiral, drawing the flower under the water after fertilization. This spiral stem, bearing the flower or pod (fig. 4), distinguishes wild celery from the other plants mentioned. The seed pod into which the pollenized flower develops is straight or curved, a little slenderer than a common lead pencil, and from 3 to 6 inches long (fig. 6). It contains, embedded in a clear jelly, small dark seeds, in number about 50 to the inch. No such pod is borne by any other fresh-water plant.

DISTRIBUTION.

Wild celery occurs naturally from central Minnesota through the Great Lake region to northern Nova Scotia, and from eastern Kansas and eastern Texas east to the Atlantic coast (fig. 7). Like wild rice it is of more or less local distribution, and consequently may be absent from considerable areas within its general range.

PROPAGATION.

Wild celery is comparatively easy to transplant. It can be propagated both by seeds and by winter buds, and the plant itself may be taken up and set out at almost any time. Floating fragments of the



B390M

FIG. 5.—Leaves of wild celery, showing venation. (Natural size.)

plant with a little of the rootstock attached, picked up in midsummer by the writer, have rooted and grown successfully. The prime requisites in propagating celery are the same as in the case of rice; the buds, plants, or seeds must not be allowed to dry or to ferment between gathering and planting. The seed pods (fig. 6) ripen from September to November and fall to the bottom. They are best collected (by net or rake) on days when the water is least ruffled during the latter half of October and early November. The winter buds

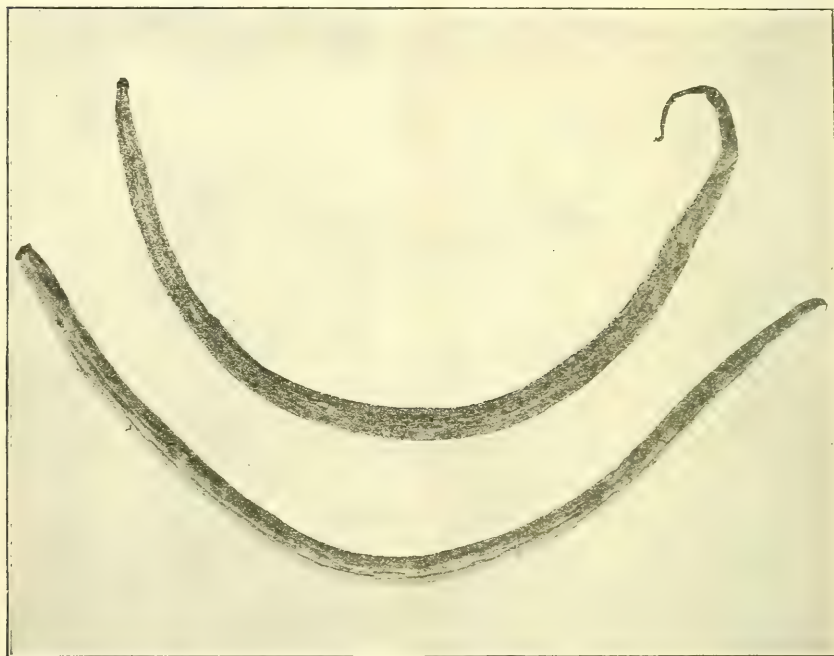


FIG. 6.—Seed pods of wild celery. (Natural size.)

B392M

(fig. 8) may be collected at the same season, before the leaves have disappeared, by following the latter down and digging up the rootstocks and buds; or the young plants may be taken up in spring just as they sprout. They should be kept moist and cool until wanted for planting, as directed for wild rice. If they must be kept for some time they should be put in open vessels of water in cold storage.

Where to plant.—Wild celery grows best on muddy bottoms in from $3\frac{1}{2}$ to $6\frac{1}{2}$ feet of fresh water, though it will grow also in sand and in both deeper and shallower water. A sluggish current suits it better than either stagnant or rapid water.

How to plant.—For sowing, the pods should be broken up (in water) into pieces about half an inch in length, which may be sown broadcast—not too thickly, as the plant spreads rapidly by root-

stocks and will soon make a dense growth. The winter buds or pieces of roots with tufts of leaves must be weighted to hold them to the bottom and enable them to take root. This may be accomplished by loosely threading several plants together and tying stones to them, or by embedding them in balls of clay. The broken seed pods also may be put into clay and dropped.

When to plant.—Where not likely to be covered by mud, the best time to sow the seed pods is in fall. Winter buds collected in fall should be kept in cold storage, and these, as well as young plants gathered in spring, should be set out in May or June.

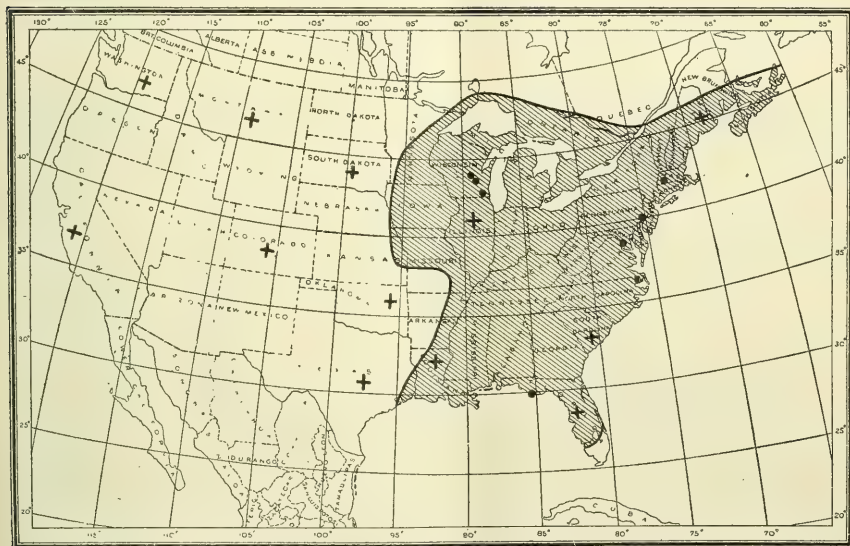


FIG. 7.—Range of wild celery. (Black spots show where it has been successfully transplanted. Crosses indicate States in which it has been propagated, the exact localities being unknown.)

PONDWEEDS.

VALUE AS DUCK FOOD.

Pondweeds (*Potamogeton*) compose a greater percentage of the food of wild ducks than wild rice and wild celery together. This is due to the wider distribution of pondweeds, allowing ducks to feed on them in winter as well as during migration and in the breeding season. There are no fewer than 38 species of pondweeds in the United States, of which at least nine (figs. 9–17) are of practically universal distribution. One of the number, the fennel-leaved or sago pondweed (*P. pectinatus*, fig. 17), produces upon the rootstocks numerous tubers (fig. 18) which are eagerly sought by certain ducks.

This one species makes up five-eighths of the whole quantity of pondweeds eaten by the canvas-back and more than a fourth of the

entire food of the bird. Thus it constitutes a slightly greater proportion of the subsistence of the bird than does wild celery. The importance of this plant was pointed out several years ago by Mr. H. L. Skavlem, of Janesville, Wis., who found that at Lake Koshkonong its tubers formed from 60 to 80 per cent of the canvas-back's food.

Besides the tubers on the roots, some pondweeds have winter buds among the leaves, and these, as well as the seeds, rootstocks, and indeed the whole plant, are eaten by ducks. As many as 350 tubers and no fewer than 560 seeds have been found in single stomachs. Pondweeds are really staple food for ducks, and nothing is more common in the stomachs than the seeds of these plants.



FIG. 8.—Propagating buds of wild celery. (Natural size.)

B393M

The many species of pondweeds present a diversity of forms. Illustrations (figs. 9–17) of the nine species of general distribution serve to show the general appearance of some of these plants. All pondweeds are eaten by ducks, and any species would be a valuable acquisition for a ducking ground.

The pondweed illustrated by figure 14 (*P. perfoliatus*) is known as redhead or duck grass, and is an important duck food, said to be especially attractive to redheads. More has been found in the stomachs of canvas-backs than of any other species. All told, 10 species of *Potamogeton* have been identified from duck stomachs, including all but one of the nine most widely ranging forms (figs. 9–17).

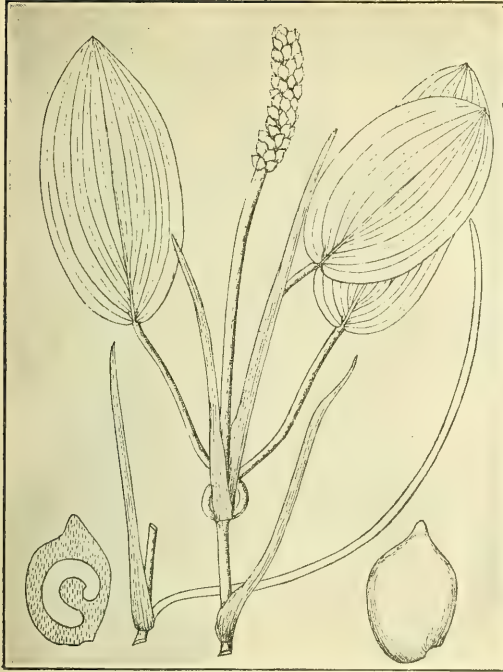


FIG. 9.—*Potamogeton natans*.

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FIG. 10.—*Potamogeton lucens*.



B396M

FIG. 11.—*Potamogeton heterophyllus*.



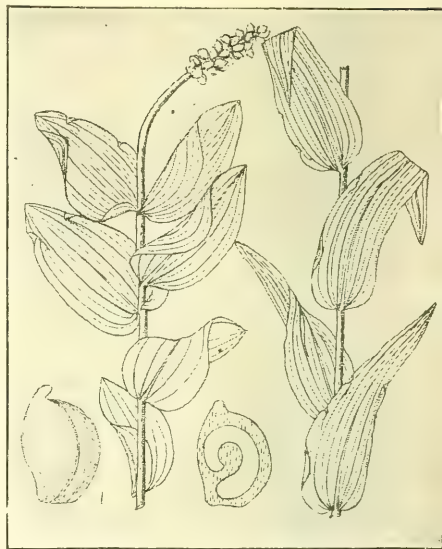
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FIG. 12.—*Potamogeton lonchites*.

FIGS. 9-12.—Wide-ranging species of pondweeds. (From Morong.)

FIG. 13.—*Potamogeton praelongus*.

B398M

FIG. 14.—*Potamogeton perfoliatus*.

B399M

FIG. 15.—*Potamogeton foliosus*.

B400M

FIG. 16.—*Potamogeton pusillus*.

B401M

FIGS. 13-16.—Wide-ranging species of pondweeds. (From Morong.)

The species of ducks and swans thus far found to feed upon pondweeds are the following: Sheldrake, red-breasted merganser, hooded merganser, mallard, black duck, Florida duck, gadwall, European widgeon, American widgeon, green-winged, blue-winged, and cinnamon teal, shoveller, pintail, wood duck, redhead, canvas-back, greater and lesser scaups, ring-necked duck, golden-eye, buffle-head, white-winged and surf scoters, ruddy duck, and whistling swan.

DESCRIPTION OF PLANTS.

The most important species, so far as known, is the sago pondweed (*Potamogeton pectinatus*). This plant has numerous, rather long, threadlike leaves, which present a loose, broomlike appearance in the water. The plant is in some places known as foxtail grass. It is known also as eelgrass, and apparently is the plant termed in Europe poker or pochard grass, after a duck closely related to our redhead. In autumn sago pondweed bears small clusters of light-brown seeds or nutlets near the surface of the water, in form somewhat like loose bunches of grapes. The other pondweeds bear seeds in the same way, and vast numbers of them are eaten by ducks.



B402M

FIG. 17.—Sago pondweed. (Reduced. From Sunset Magazine, February, 1905.)

The general appearance of sago pondweed is well shown by figure 17; note the brush of fine threadlike leaves and the seed clusters as above described. Here also are shown the tender root-stocks with their tubers, delicacies much sought by many ducks. Figure 18 illustrates the tubers natural size.

All pondweeds of the *pectinatus* group have tubers, and may therefore be substituted for sago pondweed for propagating purposes. These species are similar in general appearance and hardly distinguishable by the layman. The scientific names and general ranges of the species in the *pectinatus* group are as follows:

| | |
|--------------------------------------|--|
| <i>Potamogeton filiformis</i> | Northern States, Southern Canada. |
| <i>Potamogeton interior</i> | Ontario, British Columbia, Colorado, Utah. |
| <i>Potamogeton latifolius</i> | California, Nevada. |
| <i>Potamogeton interruptus</i> | Michigan, Saskatchewan, Nebraska. |

A pondweed with abundant tuberous rootstocks (*P. heterophyllus*, fig. 11) promises to be of exceptional value, since it changes its form and continues growth when the water surrounding it lowers or dries up. Parts of this plant for propagation are not yet on the market.

DISTRIBUTION.

The range of the sago pondweed is from coast to coast as far south as Florida, Texas, the Mexican plateau, and Lower California, north to Nova Scotia and Hudson Bay, and along the Pacific coast up to latitude 62° north (fig. 19). The distribution of other species has been indicated above.



FIG. 18.—Tubers of sago pondweed. (Natural size.)

6403M

PROPAGATION.

Sago pondweed is easily transplanted by means of the seeds, which are usually gathered with a short section of the top of the plant. Growth from seed may be so delicate as to escape notice the first season, and yet the pond may be filled the second season, for the plant grows much more luxuriantly after the root system becomes well established. Quicker results may be obtained by planting tubers, but these are rather difficult to obtain in quantity. Success has recently been achieved in transplanting young plants of this species, even after shipping them considerable distances.

Stations of the U. S. Bureau of Fisheries use pondweeds to some extent in fish ponds and no difficulty seems to be encountered in

transplanting them. Mr. Dwight Lydell, of the Michigan State fish hatchery, states that he has succeeded in propagating *Potamogeton* by means of seeds and of whole plants. He further states that



FIG. 19.—Range of sago pondweed. (Black spots show where it has been successfully transplanted.)

the most successful and largest growths have been on bottoms where the mud is about 6 inches deep over sand or clay. By mowing the plants in lakes where they are plentiful and scattering them about the ponds, no trouble has been experienced in getting a good crop.

How to plant.—Pondweeds may be transplanted on a large scale by mowing¹ the whole plants with the seeds attached and scattering about where growth is desired. The seeds alone may be collected and sown broadcast, or they may be embedded in clay balls and distributed over the bottom.

Where to plant.—Most pondweeds require fresh water, but a few species, including the sago pondweed and its relatives listed on page 17, will grow in brackish or salt water. Mud bottom is preferable, but both sago pondweed and redhead grass will grow on sand. The water in which pondweeds are planted should be from 2 to 6 feet deep.

When to plant.—The seeds may be planted immediately after gathering, or if cold storage is available they may be held until spring, as described in the case of wild rice.

Seeds of the various species ripen at different times, but in the North they may be looked for after August. Those of sago pondweed are in best condition in September and October.

ENEMIES OF WILD RICE, WILD CELERY, AND PONDWEEDS.

The three genera of plants thus far discussed—wild rice (*Zizania*), wild celery (*Vallisneria*), and pondweeds (*Potamogeton*)—vary greatly in abundance. The causes of this diversity are not well understood, but the plants have enemies whose habits are known and whose attacks may to some extent be warded off. Wild rice is generally eaten by moose, deer, and cattle, but where the damage warrants the necessary expenditure these animals can be fenced out. Muskrats tear up and eat these plants, but, so far as known, not to a serious extent. Carp also feed on them, and—

the evidence seems to be pretty strong that in general they are very destructive, and are probably in large part at least responsible for the great destruction of wild celery and wild rice that has been noted in many of our inland marshes in the last few years. This, in turn, has deprived certain ducks, especially the canvas-back and redhead, of an important food supply, and has undoubtedly influenced their abundance to some extent in the localities in question.²

In waters controlled exclusively by one interest, carp may be extirpated by partial or complete drainage and by the netting of the fish, together with the construction of wire screens or other barriers across all inlets and outlets. Where this is not practicable, systematic poisoning with fish berries or copper sulphate may succeed, but only at the expense of many forms of life besides the carp, and in the long run it might be more injurious to the duck food than to the carp. However, these methods are applicable only in small

¹ A description of the machine for mowing aquatic plants may be found in the Report of the U. S. Fish Comm., 1892, pp. 477-478.

² Cole, Leon J., Appendix Rept. Comm. Fisheries, for 1904, p. 592, 1905.

bodies of water; elsewhere effective measures against carp are impracticable

THE ARROWHEADS.

Several of the 27 species of *Sagittaria* found in the United States have leaves shaped like the points of Indian arrows, a fact that has given the group the common name of arrowheads. A number of the species, however, never have arrow-shaped leaves, the leaves being oval, lanceolate, or even without a blade in the ordinary sense of the word. Species of both groups are tuber-bearing, however, and therefore important as food for wild ducks. The species which are valuable on this account include those listed on page 2, which are not at present on the market, and the delta potato and wapato, here treated in detail.

DELTA POTATO.

VALUE AS DUCK FOOD.

In the latter part of January and early February, 1910, the writer, under authorization of the Biological Survey, visited the Mississippi Delta, La., chiefly to find out what attracts large numbers of canvas-backs to this shoal-water region, the shallow ponds and lakes of which are so different from the comparatively deep-water bodies frequented by canvas-backs in the Northern States. The attraction was found to be a tuberous species (*Sagittaria platyphylla*), known to the hunters of this and other parts of Louisiana as wild potato or wild onion. From an examination of a large number of stomachs it was found that about 70 per cent of the food of the canvas-backs collected consisted of the tubers of this plant, as did also more than 65 per cent of the food of the mallards. The pintail also fed upon the tubers. The gullet of one canvas-back was filled to the throat with the delta potatoes, 24 entire ones being present, besides ground-up remains of several others. Other individuals had 14 to 17 of the tubers in their gullets. There is no doubt that *S. platyphylla* is an important food for the larger species of ducks, not only in the Mississippi Delta, but throughout the whole range of the plant.

DESCRIPTION OF PLANT.

The delta potato (fig. 20), when well developed, stands about 18 inches above the soil. The broadly elliptical leaves have a characteristic firm appearance and a beautiful clear green color. Like all plants of its genus, this species produces flowering peduncles from about the center of the group of leafstalks; these peduncles bear flowers in whorls of three, and the individual flowers each have three white petals and a yellow center. The petals soon fall and the small green balls of immature seeds remain. These enlarge during the

summer, and when ripe are brown and nearly half an inch in diameter. They are easily crushed, separating into hundreds of thin triangular seeds.



FIG. 20.—Delta potato. (Scale is 18 inches long.)

B365M

The tubers are of irregular globular shape and vary up to an inch in diameter. They are formed at the ends of runners (thicker than the fibrous roots) and bear on the side opposite the attachment to the runner a scale-sheathed bud which may be an inch or more in length.

Running around the body of the tuber are two or three darker lines from which originate fibrous sheaths. A glance at the illustration of the tubers (fig. 21) of this species shows the aptness of the name "wild potato." It should be explained, however, that normally the tubers are more widely separated than is the case with those on this particular specimen, which was grown in a flower-pot.

DISTRIBUTION.

In ancient times the Mississippi River emptied into a vast bay which extended at least as far north as the region now known as



FIG. 21.—Tubers of delta potato. (About two-thirds natural size.)

B355AM

southern Illinois. Its actively growing delta (which is still apparently in full vigor) made thick deposits of silt over some thousands of square miles of this area while the remainder was being slowly elevated. *Sagittaria platyphylla* is so nearly confined in its distribution to this ancient basin, and is so characteristic of the present delta, that the name delta potato is eminently fitting. The outlying points of the range of the plant as now known are San Antonio, Tex., Lake City, Mo., Chattanooga, Tenn., and Mobile, Ala. (fig. 22).

PROPAGATION.

The delta potato undoubtedly can be propagated from seed, but, all things considered, transplanting the tubers is probably much the better method. This insures a large percentage of success, the plants will be larger, and as they will produce other tubers the first year they are much more valuable. Extraordinary precautions to prevent drying are not necessary, but the tubers should be kept cool and well exposed to the air to prevent heating or fermentation.

To plant, embed the tubers in mud bottom where the water is not more than a foot deep, preferably not more than 6 inches. It is better to err on the shallow side. The plant will grow thriftily on soil never covered by water but which has plenty of moisture. In such situations, however, the tubers are not available to ducks unless over-

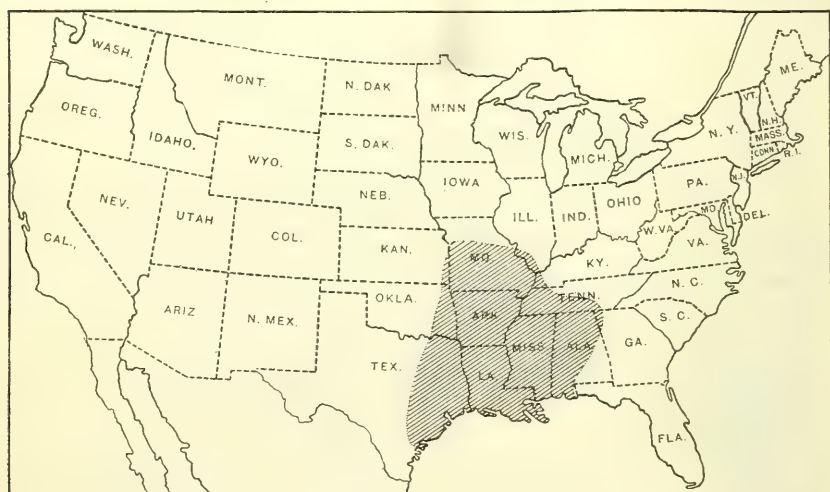


FIG. 22.—Range of delta potato.

flowed in winter. The delta potato is not injured by a slight quantity of salt in the soil. The plant is probably hardy anywhere in the southern half of the United States and may prove to be so farther north.

WAPATO.

VALUE AS DUCK FOOD.

The tubers of the wapato (*Sagittaria latifolia* and *S. arifolia*) have been known to white men as an important food for wild fowl since the time of the Lewis and Clark expedition of 1804–6. These famous explorers state that in the Columbia River valley large numbers of ducks, geese, and swans occur where this plant is abundant

and that the swans in particular feed extensively upon the plant. A correspondent of the Biological Survey, Mr. George W. Russell, of Gaston, Oreg., writes that the wapato is fed upon most by the diving ducks, as the canvas-back, redhead, and bluebills (scaups), and that they seek it whenever they are present in the country where it grows. Prof. David Dale Owen, in his report of a geological survey of Wisconsin, Iowa, and Minnesota, notes that these tubers afford much nourishment to the larger aquatic fowls. The vernacular names swan potato and duck potato that have been applied to these plants give further evidence of their value to wild fowl. Other local names are swamp potato, muskrat potato, Chinese onion, and water nut. The Biological Survey has found various parts of *Sagittaria* plants in stomachs of the following species of waterfowl: Mallard, widgeon, green-winged teal, blue-winged teal, spoonbill, pintail, canvas-back, little blue-bill, ruddy duck, Canada goose, and whooping swan.

DESCRIPTION OF PLANT.

The general relations of stems, flowers, and tubers are the same in the wapato (fig. 23) as in the delta potato (fig. 23) as in the delta potato, but the shape of the leaves is entirely different. Both *Sagittaria latifolia* and *S. arifolia* have arrowhead-shaped leaves. These vary greatly in the length, width, and shape of the point and barbs and in the degree of divergence of the latter. Various forms of leaves are illustrated in figure 24. The wapato plant sometimes reaches a height of 4 feet. The appearance of the flowers and seed balls is much the same as in the delta potato.

The tubers of *S. latifolia* (fig. 25), from six to nine to the plant, are formed on runners in the same manner as those of the delta potato,

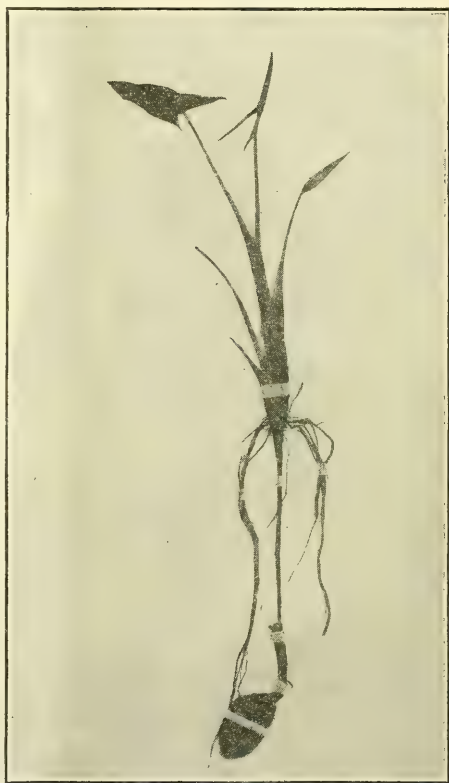


FIG. 23.—Young eastern plant of wapato with single tuber. (Two thirds natural size.)

B569M

but they attain a much larger size. The largest specimen examined by the writer was 2 inches in its longest diameter and 1 inch thick. Including the bud and a short stalk at the base, the entire tuber may measure as much as 5 inches in length. The mature tubers of plants from the Northwest are more or less flattened, the shape being comparable to that of the ordinary edible crab. The smaller tubers are more nearly spherical (varying to ovoid), and this is the shape of even the largest tubers of eastern plants that the writer has seen. The sheaths of the tuber, being of a darker color than the body, are conspicuous.

DISTRIBUTION.

Sagittaria latifolia is found from the Atlantic coast to the Pacific, its range covering practically the whole United States (fig. 26). Areas from which it apparently has not been reported are peninsular Florida, the southern two-thirds of Louisiana and Texas, New Mexico, Arizona, and southern California. The northern limit of its range is marked by the following localities: Vancouver Island, Saskatchewan



FIG. 24.—Various shapes of wapato leaves. (About one-tenth natural size.)

River, and southern Ontario and Quebec. *Sagittaria arifolia* is confined to States from Michigan and Kansas westward. Its range is largely included in that of *S. latifolia*, although it has been collected in New Mexico. The two species are distinguishable with certainty only upon the basis of mature seeds, and for all practical purposes may be considered as one.

PROPAGATION.

The wapato may be transplanted by means of both seeds and tubers,¹ but the latter are the most reliable and give the quickest results. They may be set with the bud just beneath the surface in mud bottom under a foot of water or preferably less. The plants will grow in

¹ It is probable that tubers of *Sagittaria chinensis*, which are in market wherever there is a large Chinese colony, and which are also on sale by seedsmen, may be substituted for those of wapato with satisfactory results.

wet soil, but the tubers are not available for duck food in such places unless overflowed in fall and winter.

The tubers of this plant are known to retain their vitality when dried, but more uniform success will probably result if drying is not

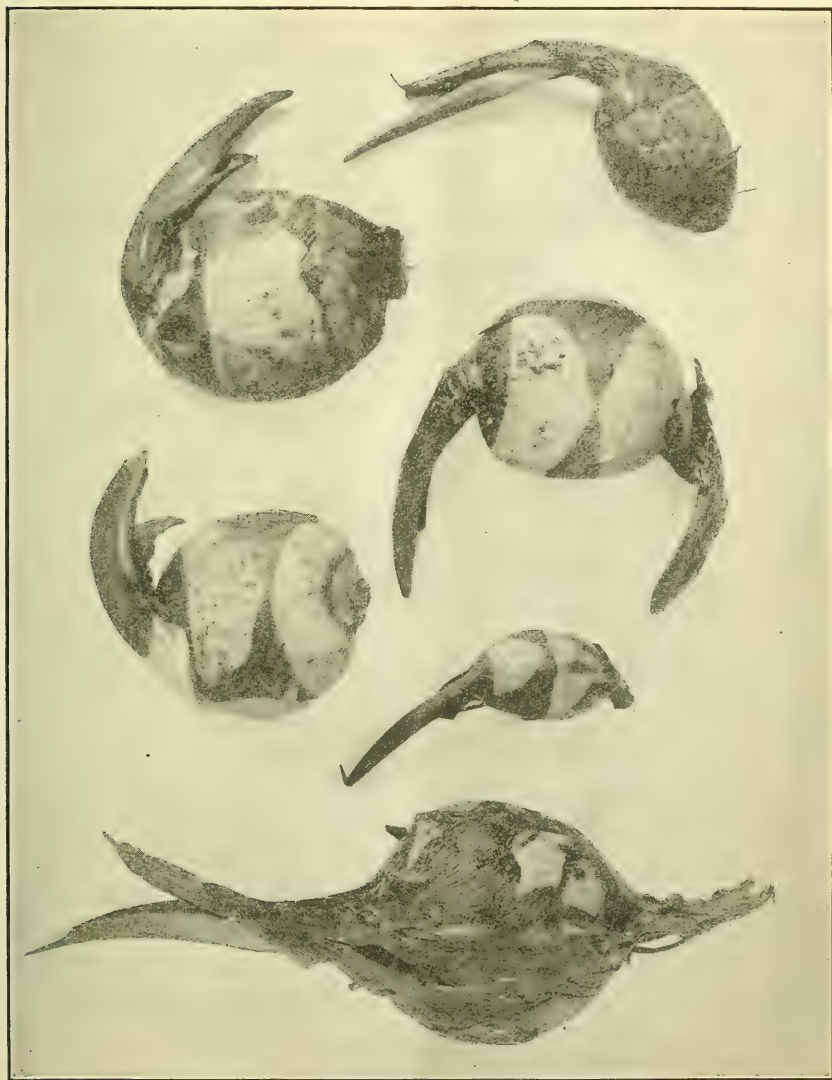


FIG. 25.—Wapato tubers. (About two-thirds natural size.)

B538M

carried to an extreme. Tubers should be shipped promptly after gathering, in well-ventilated packages, and should be planted immediately upon receipt. The wapato is suitable for cultivation in practically all parts of the United States.

CHUFA.

VALUE AS DUCK FOOD.

Like some of the other duck foods mentioned in this bulletin, chufas (*Cyperus esculentus*) are at present known to be of only local importance. Those best acquainted with conditions at Big Lake, Ark., formerly one of the most famous hunting grounds of the South, now a national bird-reservation, believe that the chufa, or nut grass as it is there called, is the principal element in rendering that lake so attractive to waterfowl. Examination of stomachs from that locality seems to justify this belief. Six of a series of nine mallards collected at Big Lake in December, 1910, had fed on sedge tubers, the average

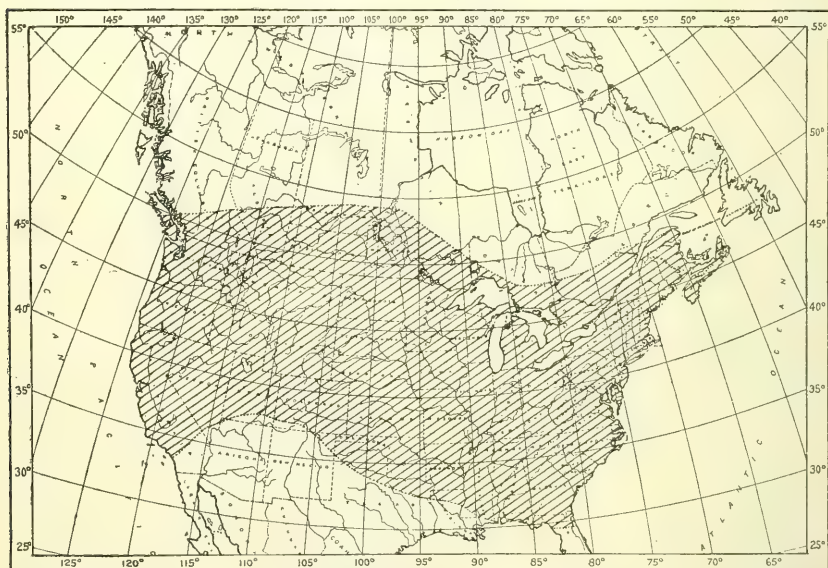


FIG. 26.—Range of the wapato.

percentage of which in the food of the nine was 56. Tubers of this species, or others of its genus, have been found also in duck stomachs from Florida, Illinois, Minnesota, and California. The species of ducks now known to feed on chufas are the wood duck, mottled duck, mallard, and canvas-back.

DESCRIPTION OF PLANT.

The chufa (fig. 27) belongs to the group of plants known as sedges. These are grasslike and are usually classed with grasses by nonbotanists. Many of the sedges, however, including the chufa, have triangular, not round, stalks. The members of the genus *Cyperus* have a group of leaves at the base from which rises the stalk bearing the flowers and seeds. In the chufa these stalks are

from 1 to 3 feet high. Several flower clusters on peduncles of varying length rise from the top of the stalk. From the same point three rather long, grasslike leaves project below the fruiting clusters.

Many members of the genus have a very similar appearance, and it is not likely that nonbotanical observers will distinguish them.



FIG. 27 —Seed-bearing and immature plants of chufa. (Much reduced.)

B568M

This is unnecessary, however, as tubers of the chufa may be obtained for propagation from most seedsmen. The tubers are formed at the ends of scale-covered rootstocks. The plant is extremely prolific, cultivated forms usually producing 100 tubers to the plant, and instances are known in which more than 600 tubers were produced in one season from one tuber planted in spring.

Well-developed tubers of the cultivated variety average about three-fourths of an inch in length by three-eighths of an inch in diameter when dried. Tubers from wild plants are usually much smaller and have a greater proportion of fiber. The general appearance of chufas and of tubers from a wild sedge is well shown in figure 28.

Chufas are known also by the vernacular names earth almonds and ground nuts, and the plant as nut grass and cache-cache.

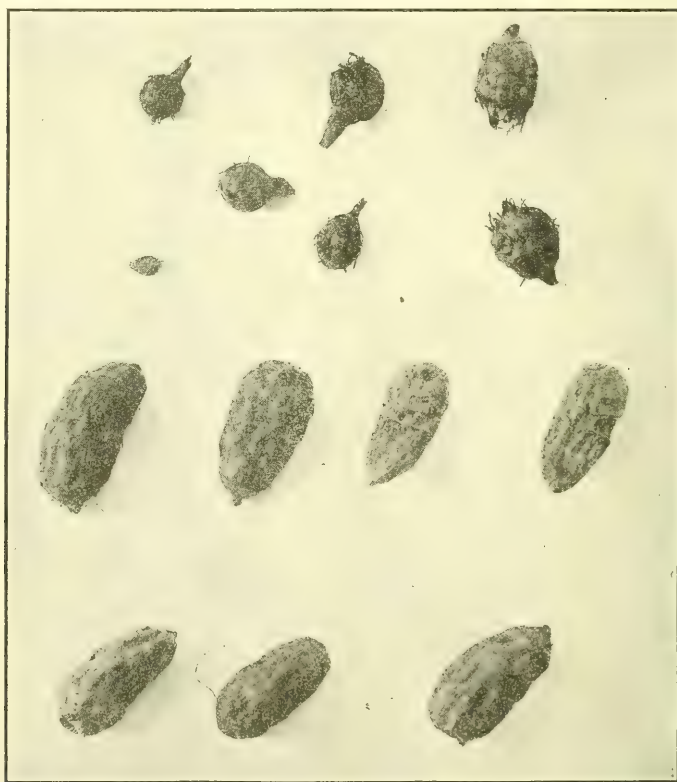


FIG. 28.—Tubers of wild and cultivated chufas. (Natural size.) ^{B527M}

DISTRIBUTION.

The northern boundary of the natural range of the chufa is marked by the following localities: Southern New Brunswick, southern Ontario, northern Nebraska, New Mexico, Arizona, and the Columbia River valley. The plant seems to be absent from most of the Great Basin and Rocky Mountain regions. From its northern limit the plant ranges southward over the remainder of the continent. (See

fig. 29.) It is widely distributed in warm climates over the entire world.

PROPAGATION.

Although the chufa seems not to grow naturally in a large area in western United States, there is no doubt that it can be cultivated everywhere except in the higher parts of the Rocky Mountain region. It is said to do fairly well at the altitude of Denver.

Chufas can be obtained from most seedsmen and are so cheap that it will pay sportsmen to buy new stock every few years, if earlier plantings show degeneration in size of tubers and hence reduction in value as duck food. Chufas do best on light or somewhat sandy but rich soils. They are available for duck food only when planted



FIG. 29.—Range of the chufa.

on land dry in summer and overflowed in winter. In the open they should be planted thickly so as to give the plants a better chance in competition with weeds. In timbered land they need not be planted so thickly, but they will do well in only rather sparse growths, where considerable light penetrates to the ground. When possible the land intended for planting should be broken up and freed from weeds. The tubers should be planted just beneath the surface in spring.

WILD MILLET.

VALUE AS DUCK FOOD.

Wild millet (*Echinochloa crus-galli*) is an important food for ducks in widely separated regions of the United States. At Mud Lake, Ark., the writer found seeds of this plant to constitute more than 10 per cent of the food of 41 mallards collected; at Belle Isle, La., it made up more than half the food of the few mallards examined; and at Cameron, La., over 75 per cent of the diet of a collection of 50 ducks of the same species. Pintails, teal, and other shoal-water ducks are almost equally fond of it. Geese eat the stems and leaves of the plant, as do also ducks when they are hard pressed. Testimony as to the value of the plant as a wild-duck food has come from Wisconsin and Oregon, and the Biological Survey has found seeds of wild millet in duck stomachs from Massachusetts, South Dakota, Missouri, and Nebraska in addition to the States mentioned.

The plant is popularly known throughout lower Louisiana as wild rice and is given about the same rank as a duck food as the plant (*Zizania aquatica*) known by that name in the North. Other popular names referring to the preference of wild fowl for the plant are goose grass and blue-duck food.

DESCRIPTION OF PLANT.

Wild millet is a coarse, leafy grass which grows from 1 to 6 feet in height. The stems and foliage are not especially remarkable, but the fruiting head has characters which enable one easily to distinguish this from other species of native grasses. The chaff or outer seed covering is set with rows of short, stiff, outstanding spines. These project beyond the general outline of the body of the seeds and give them an easily visible spiny appearance (fig. 30). The inner scale of the chaff terminates in a spine which is always stouter and longer than the others. This spine or awn may be very short, or it may be from 2 to 3 inches or more in length, surpassing by many times the length of the seed. One of the other scales also may bear a long spine at the tip. The prickly character of the seed coverings is referred to in the name cockspur grass. The longer awns in particular, and sometimes the whole fruiting heads, may have a deep purplish color. This, no doubt, suggested the name blue-duck food used in the Mississippi Delta. The long-awned form has been given the varietal name *longearistata* but for present purposes we may consider all the types illustrated in figures 30 and 31 under the same name. It is probable also that the form named *Echinochloa walteri* is fully connected with *E. crus-galli* by intergrades and deserves only varietal rank. This form has the lower or all-leaf sheaths rough hispid.



FIG. 30.—Part of fruiting head of wild millet. (Natural size.)

B671M

DISTRIBUTION.

The northern limit of the range of wild millet so far as known does not much surpass the latitude of the northern boundary of the United States. From there the plant ranges indefinitely to the southward, occurring generally in rich moist soils or swamps at least to Central America.

PROPAGATION.

Wild millet is easily cultivated and reseeds itself. It requires a moist and preferably a rich soil, as the edge of a marsh or lake, and will grow in water at least a foot in depth. The soil should be



FIG. 31.—Fruiting heads of wild millet. (One-third natural size.)

B570M

broken up (mainly for the purpose of discouraging other plant growth) and the seeds sown thickly in spring. Once established, the plant will take care of itself. The nearer to water it is planted the more available will it be for duck food. It is a splendid plant to use for lowlands that are flooded in winter.

The seeds are sold by most seedsmen under the name barnyard grass. A variety has been widely advertised as Japanese barnyard millet or billion-dollar grass. The plant is also known as cockspur grass and sour grass. It may be cultivated in any part of the United States having the proper soil conditions.

THE WATERLILY GROUP.

The waterlily group as represented in the United States is variously considered to comprise from one to three families. One of the three families (Cabombaceæ) is distinguished by having the seeds borne separately, each with its own closely fitting covering; these plants have small uncleft circular or oval leaves on central stalks. The second family (Nelumbonaceæ) has the large acornlike seeds in open cavities in a thick funnel-shaped receptacle; these plants have large uncleft circular leaves on central stalks. The third, or waterlily, family (Nymphæaceæ) has the numerous seeds entirely inclosed in a fleshy, leathery, urn-shaped fruit; the leaves of these waterlilies are cleft from the edge to the point of attachment of the leaf stalk.

The Cabombaceæ include two plants of the United States, only one of which is known to have noteworthy value as a wild-duck food. This is the water shield (*Brasenia schreberi*, known also as *B. peltata*, and *B. purpurea*), which is found in ponds and slow streams throughout the United States. Other vernacular names for this plant are frogleaf and little waterlily. The seeds only are eaten, but they have been found in the stomachs of 19 species of ducks, including the wood duck, Florida duck, mallard, black duck, buffle-head, golden-eye, pintail, ruddy duck, widgeon, lesser and greater scaups or bluebills, red-head, ring-necked duck, canvas-back, green-winged and blue-winged teals, white-winged and surf scoters, and shoveller. No fewer than 120 seeds of water shield were found in a single stomach of a mallard, and 380 in one of a wood duck.

The family of nelumbos, or lotuses, has only one native species (*Nelumbo lutea*) in the United States, and it is locally distributed almost throughout the eastern half of the country. This plant has a variety of vernacular names, among which are water chinkapin, wankapin, yankapin, duck acorn, rattle or water nut, and yawknut, and, among the French-speaking people of Louisiana, vole and grand ovale. Locally it has considerable repute as a food for wild ducks, especially the wood duck.

The third, or waterlily, family consists of two genera, the cow-lilies or spatterdocks (*Nymphæa*) and the true waterlilies (*Catalia*). The name *Nymphæa* long was applied to the latter group and is yet by some authorities. It is customarily used in this sense also in trade publications. The spatterdocks have yellow flowers with five or six leathery sepals, and the petals though numerous are inconspicuous. The waterlilies, on the other hand, have numerous conspicuous petals, which in our species are white, pink, blue-striped, blue, or yellow.

The spatterdocks, known also as pond, cow, toad, frog, dog, horse, or beaver lilies, beaver-root, and bonnets, are held to comprise 17 species distributed throughout North America, the best known of which is *Nymphaea* or *Nuphar advena*. These grow in shallow water of ponds or slow streams. Only the seeds have distinct value as wild-duck food. They have been found in stomachs of the mallard, black duck, pintail, green-winged teal, lesser scaup, and wood duck. No fewer than 160 seeds were in one stomach of the last-named species.

The true waterlilies of the United States belong to seven species. Among their vernacular names are pondlily, water cabbage, and alligator blankets. Seeds of these waterlilies are known to be eaten by the following 13 species of ducks: Wood duck, black duck, Florida duck, pintail, green-winged teal, lesser and greater scaups, redhead, ring-neck, canvas-back, widgeon, shoveller, and golden-eye. Large numbers of seeds found in single birds are 320 in a ring-neck duck, and 200 each in a lesser scaup and a ruddy duck.

PROPAGATION.

All the species of the waterlily group may be propagated either by seeds or rootstocks, and parts for propagating many of them are on the market. All grow in rather shallow, quiet, or slow-moving water, and prefer mucky bottom. The water chinkapin and the spatterdocks sometimes grow in water only a few inches deep, where the leaves and flower stalks stand erect. The true waterlilies, on the other hand, may grow in water six feet deep. The tuberous waterlily is especially valuable, because it will survive temporary drying up of the water body in which it grows. Probably the most valuable species of this group, however, is the banana waterlily, which is here treated in detail.

BANANA WATERLILY.

VALUE AS DUCK FOOD.

The writer has investigated the value of the banana waterlily (*Castalia mexicana*) as a food for wild ducks in only one locality—Lake Surprise, Tex. The proofs of its importance are so great, however, that they should be brought to the attention of American sportsmen. At Lake Surprise the banana waterlily alone made up nearly half of the entire food of the 10 vegetarian species of ducks occurring there at the time. This showing is much more significant from the fact that sago pondweed (*Potamogeton pectinatus*) also was abundant in the lake. The latter plant (see p. 17), in the writer's opinion, is the best all-round duck food in North America, yet at Lake Surprise it furnished somewhat less than 29 per cent of the food of the ducks, in comparison with more than 48 per cent supplied by *Castalia mexicana*.

Thirty-seven canvas-backs collected at Lake Surprise had eaten various parts of this plant to the extent of 71.6 per cent of their diet. This is a second illustration of the unusual phenomenon of the canvas-back's being attracted to shallow water by a highly prized food. Six ring-neck ducks, or blackjacks, made more than 91 per cent of their food of this plant, and two southern black ducks (*Anas fulvigula*) 98 per cent. The following ducks also were feeding on the plant: Mallard, pintail, lesser scaup, redhead, and shoveller. The parts eaten are the rootstocks, stolons, tubers, and seeds. Mr. Charles W. Ward has furnished rootstocks of *Castalia mexicana* from Avery

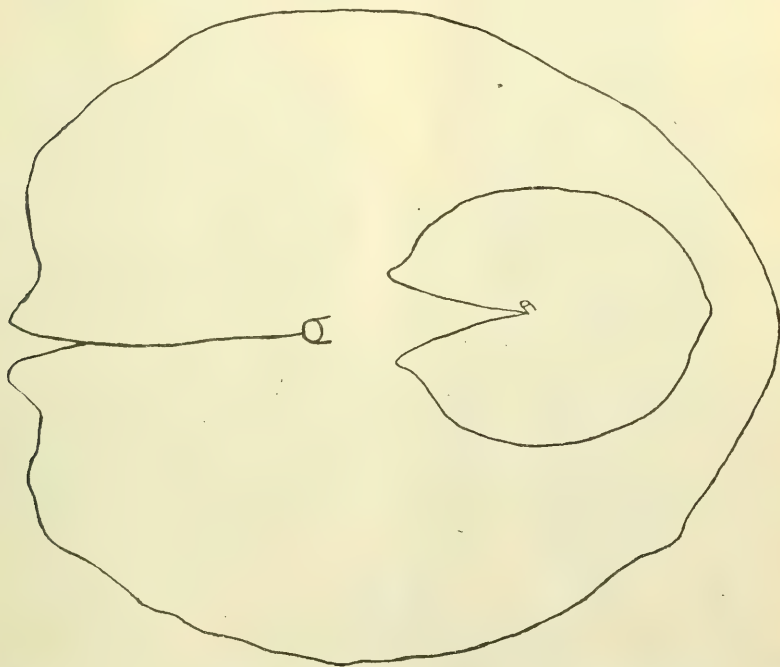


FIG. 32.—Two types of leaves of banana waterlily. (The larger outline half natural size.)

Island, La., with the information that this plant and wild celery (*Vallisneria spiralis*) furnish the bulk of the food of canvas-backs in that locality.

DESCRIPTION OF PLANT.

The banana waterlily is the only native species of the group of true waterlilies (as discussed above) that has yellow flowers. But the leaves and flowers of this species may either float on the surface of the water or stand a few inches above it. The leaves are green above with brown mottlings and vary from greenish to purplish red below with small black markings. The edges of the cleft of the leaf are either somewhat separated or overlapping (fig. 32). The

plant springs from an upright rootstock (fig. 33) which bears some resemblance to an unopened pine cone. The rootstocks vary in size

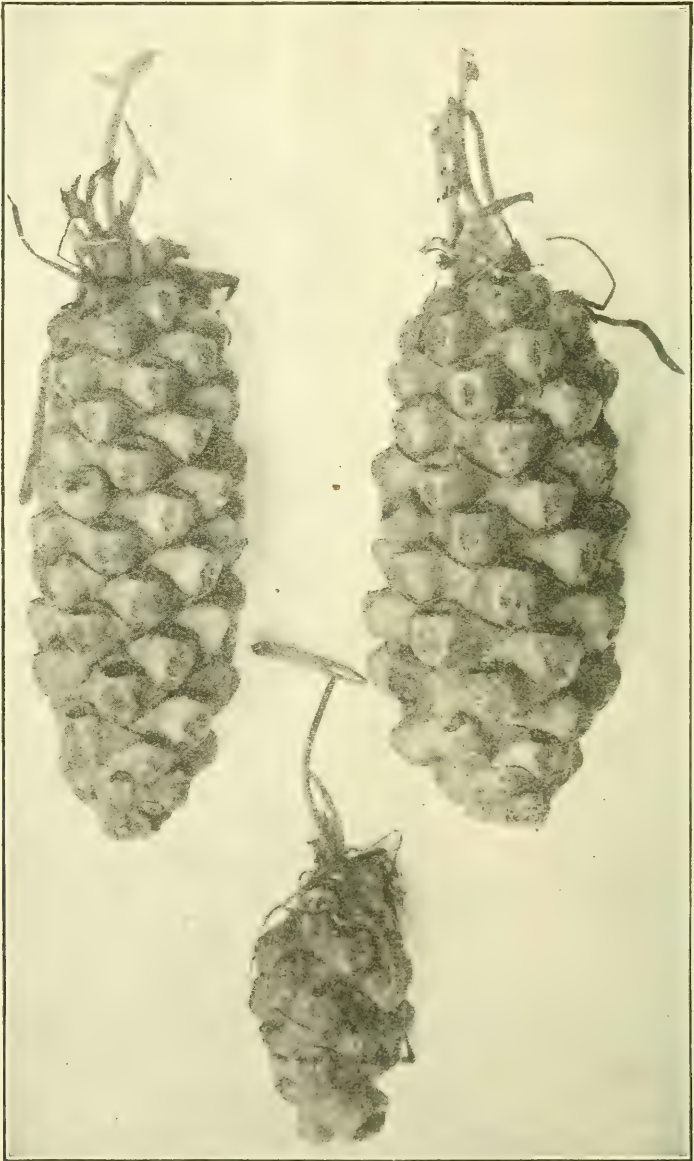


FIG. 33.—Small rootstocks of banana waterlily. (Natural size.) B235M

up to 2 inches thick and 12 inches long. The smaller ones (at least up to $1\frac{3}{4}$ inches long by three-fourths of an inch thick) are swallowed by ducks.

Tender white stolons or runners extend in various directions from the rootstock. These runners are from a quarter to half an inch in diameter. During the active growing season they give rise to new plants, but in autumn they form peculiar hibernating bodies. These consist of the short modified tip of the stolon, which bears several (1 to 7) upwardly directed buds on one side and a cluster (2 to 17) of thick tuberlike roots on the other. The appearance of these (fig. 34) is strongly suggestive of a miniature "hand" of bananas, and for this reason the name banana waterlily has been proposed for this plant, which has no distinctive vernacular appellation. The name has the additional merit of suggesting the yellow color of the tubers and of the flowers.



FIG. 34.—Hibernating bodies of banana waterlily. (Two-thirds natural size.)

DISTRIBUTION.

The banana waterlily has been known chiefly as a native of Florida, and the plants of that State have long gone under the name *Castalia flava*. Plants identified from a few localities in Mexico and from Brownsville, Tex., have been called *C. mexicana*. Dr. H. S. Conard, who has monographed the genus,¹ unites these species, as he is fully justified in doing, on the basis of their possession in common of characters unique among waterlilies. The new records of the plant from Galveston, Tex., and Avery Island, La., go far toward bridging the previous apparent gap in distribution of the plant and toward corroborating Dr. Conard's views. The accompanying map (fig. 35) shows the probable natural range of the species along the Gulf coast and in Mexico.

¹ Publication No. 4, Carnegie Institution, 1905.

PROPAGATION.

Although the banana waterlily is native to only a small portion of the United States, it can be successfully grown over practically the whole country. The plant has long been familiar in cultivation and is sold by most dealers in ornamental aquatics. The waterlily expert of one of the largest firms in the United States reports that *Castalia mexicana* is perfectly hardy as far north as New York City when covered with a foot of water, and he believes that if covered with 2 feet of water it would be hardy at Boston.



FIG. 35.—Range of banana waterlily.

The banana waterlily needs an abundance of sunlight, water from 1 to 3 feet deep,¹ and a mud bottom. It is not injured by a trace of salt, as is shown by its growing in lakes very near the coast. The rootstocks may be planted by weighting them with stones and dropping where desired. Having great vitality, they may be shipped with only moderate precautions to prevent them from drying, and may be transplanted at almost any time of the year.

¹ When established it will spread to places where the water is even 5 feet deep.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 466

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief



Washington, D. C.

PROFESSIONAL PAPER

November 3, 1917

MAPLE SUGAR: COMPOSITION, METHODS OF ANALYSIS, EFFECT OF ENVIRONMENT.

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INTRODUCTION.

A previous publication¹ of the Bureau of Chemistry dealing with the manufacture of maple-sap sirup gives the distinguishing features of sap sirup and sugar sirup, as well as the results of the chemical examination of 481 samples of sap sirups. The present bulletin deals with the methods of analysis and the composition of maple sugars examined in the former Sugar Laboratory of the Bureau of Chemistry in connection with the previous report and of samples collected during the seasons 1910, 1911, and 1912. It is believed that this report may be useful to food chemists who are called upon to examine maple products.

DEFINITIONS.

As maple sirup is the sap of the live maple tree concentrated to a standard density, with or without the addition of the usual clarifying agents, maple sugar is the solid product resulting from the further concentration of the sirup or of the sap, with or without the addition of clarifiers, and without the loss of any of its constituents other than

the solids precipitated by the concentration. United States Department of Agriculture, Office of the Secretary, Food Inspection Decision 161, January 3, 1916, states that "*Maple sugar, maple concrete*, is the solid product resulting from the evaporation of maple sap or maple sirup. *Maple sirup* is sirup made by the evaporation of maple sap or by the solution of maple concrete, and contains not more than thirty-five per cent (35%) of water and weighs not less than eleven (11) pounds to the gallon (231 cu. in.)."

The maple sugar of commerce may be divided into soft or hard sugar or into stirred sugar (sometimes called grain sugar), cake sugar, and tub sugar.

The terms hard sugar and soft sugar apply to the relative hardness of the product; a sugar is said to be hard when it is difficult to break the cake and soft when the cake is easily broken. Hard sugar contains less moisture than soft sugar and is produced by boiling to a higher temperature; that is, by boiling it longer. Determinations of moisture in these two grades are given in tabular form on page 39.

The terms stirred, cake, and tub sugar apply to the form in which the finished product is placed upon the market.

Stirred or grain sugar, sometimes called "crumb" sugar, derives its name from the fact that it is concentrated to a rather high degree, then stirred during cooling and crystallization. The finished product resembles the ordinary commercial brown sugar, and as a rule is dry and slightly lumpy. The color varies from off white to light brown, although there are some dark varieties. It is not often found on the open market, being made mostly for consumption in the farmer's home. Certain sections of the country, however, as Pennsylvania, produce a large quantity of their maple products in this form.

Cake sugar, which may be either soft or hard, is so named because it is molded in the form of cakes varying in size from the 1-ounce cakes of the fancy confectionery trade to those weighing several pounds. The fancy cakes as a rule dissolve readily in the mouth, while the hard cakes are not easily broken by the teeth and can be shipped without cracking. The larger cakes are known as brick sugar. The color varies from off white to black. Imported maple sugar is usually very dark colored. The darker varieties are strong flavored and have more or less taste of caramel.

Tub sugar may be classed as a soft sugar. It gains its name from the fact that the makers concentrate their sirup to the desired density, cool slightly, and then run it into tubs of from 10 to 50 pounds capacity, with an average of 25 pounds. These containers are generally wooden, although tin is sometimes used for fancy trade. Much of the tub sugar is of a low grade and very dark. Often it is in a "mushy" condition and drains badly.

SAMPLING.

In the case of grain sugar or cake sugar that is hard and dry, sampling is comparatively easy, but with tub sugar or wet cake sugar there is more difficulty, because the liquid portion has drained to some extent and may have left practically pure sucrose. Maple sugar is principally sucrose, or the sugar of commerce, with a mother liquor surrounding the crystals which gives it its particular characteristic qualities. Were the mother liquor removed completely from the crystals of sugar, one would have the ordinary sugar of commerce, granulated sugar or sucrose. Maple sugar brings its high price not on account of the sugar it contains but because of the agreeable flavoring substances which are present in the mother liquor. It is easily argued, then, that if this mother liquor is removed in part the product is not maple sugar, and a person buying it would not be buying maple sugar. With this point of view, it is necessary in sampling a tub of maple sugar or of any soft sugar to see that the product is thoroughly mixed before a sample is drawn, and that the sample represents both the sugar and the proportionate quantity of the mother liquor.

METHODS OF ANALYSIS.

It is the general practice in the manufacture of maple sugar not to skim or remove the mineral matter which is separated during the boiling and concentration of the sirup; many makers cake the skimmings and settlings, considering that such a procedure does not injure the product in any way and gives it a larger volume. In the production of fancy cake sugar the manufacturer usually skims and removes all sediment carefully before the final boiling for the caking of the sugar. It will be readily seen that the sugar made without skimming or filtration will have a much higher ash content than that which has been carefully cleansed before caking. In order to place all sugar samples upon a comparative basis, it is necessary in the preparation of the sample for analysis to dissolve the sugar and remove the suspended mineral and organic matter. Samples of maple sugar, especially of that made from skimmings and settlings, have been found with an ash content as high as 3 per cent, while sugar made from carefully cleansed sirup sometimes contains as little as 0.77 per cent. If the analysis were made on the sugar itself, it would be possible to add nearly two-thirds white sugar and make a product which, according to the ash, would not be suspected of adulteration, but if this adulterated sugar were made into sirup and the substances foreign to the sugar held in suspension were removed, the ash content would be so reduced that adulteration of two-thirds white sugar would be readily seen.

Jones,¹ recognizing this, recommended that all maple sugar be dissolved to a standard sirup of 11 pounds to the gallon, filtered, and the sirup analyzed, to effect a more certain determination of the presence or absence of adulterants. By this treatment, even with the highest grades of pure maple sugar, he has never obtained a sirup having chemical characteristics which would place it in the list of adulterated products. He states that "It would seem, therefore, that a certain minimum amount of ash can not be removed from pure sugar or sugar made into sirup by the ordinary methods of filtration and that even the slow and complete filtering which is effected by this method fails to remove sufficient ash from the pure goods to admit even a suspicion of adulteration."

The effect of the treatment just described is readily seen in Table I, where the results of the eight samples of maple sugar analyzed as sugar and then analyzed in the sirup condition are tabulated, the individual determinations in all cases being calculated to the moisture-free basis.

TABLE I.—*Analysis of maple sugar as sugar and as sugar sirup.*

| Sample No. | Sugar. | | | | Sirup. | | | |
|--------------|------------------|------------------|------------------|---------------------|------------------|------------------|------------------|---------------------|
| | Total ash. | Insoluble ash. | Soluble ash. | Winton lead number. | Total ash. | Insoluble ash. | Soluble ash. | Winton lead number. |
| | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | |
| 1..... | 0.93 | 0.42 | 0.51 | 2.12 | 0.87 | 0.32 | 0.55 | 2.18 |
| 2..... | .89 | .36 | .53 | 2.14 | .79 | .29 | .50 | 2.05 |
| 3..... | 1.28 | .63 | .65 | 3.28 | .84 | .23 | .61 | 2.36 |
| 4..... | .98 | .38 | .60 | 2.51 | .82 | .24 | .58 | 2.40 |
| 5..... | .95 | .42 | .53 | 2.46 | .79 | .24 | .55 | 1.93 |
| 6..... | 1.22 | .67 | .55 | 3.25 | .83 | .23 | .60 | 2.29 |
| 7..... | 1.35 | .76 | .59 | 3.38 | .85 | .23 | .62 | 2.35 |
| 8..... | 1.20 | .66 | .54 | 3.16 | .84 | .23 | .61 | 2.15 |
| Average..... | 1.10 | .54 | .56 | 2.79 | .83 | .25 | .58 | 2.21 |

In the sugar state the total ash varied from 1.35 to 0.89 per cent, a variation of 0.46 per cent, with an average of 1.10 per cent, while after making the sugar into sirup the range was from 0.87 to 0.79 per cent, or a variation of only 0.08 per cent, with an average of 0.83 per cent. In the filtration process 0.27 per cent of ash had been removed, which corresponds practically to the loss in insoluble ash. The soluble ash remained practically the same, corroborated again by the fact that analysis of the precipitate gives only small percentages of sodium or potash salts. The lead number decreased from an average of 2.79 to 2.21 per cent, with variations of the sugar from 3.38 to 2.12, or 1.26 per cent, and of the sugar sirup from 2.40 to 1.93, 0.47 per cent. Here again by analyzing the product in the form of a sirup the maximum and minimum results are brought closer together and adulteration is more easily detected. These figures agree with those obtained by Jones.¹

¹ Vt. Agr. Exp. Sta., 17th Ann. Rpt. (1904), p. 453; 18th Ann. Rpt. (1905), p. 327.

TABLE II.—*Comparison of sugar and sirup results (Jones).*¹

| Maple sugar. | | Sirup from same sugar. | | Calculated to dry basis from approximately 65 per cent solids. | |
|----------------------------------|---------------------------------|---------------------------------|---------------------------------|--|---------------------------------|
| Total ash. | Insoluble ash. | Total ash. | Insoluble ash. | Total ash. | Insoluble ash. |
| <i>Per cent.</i>
0.80
1.08 | <i>Per cent.</i>
0.34
.64 | <i>Per cent.</i>
0.56
.52 | <i>Per cent.</i>
0.22
.18 | <i>Per cent.</i>
0.86
.80 | <i>Per cent.</i>
0.34
.28 |

¹ Jones does not state that the figures on "Maple sugar" were calculated to a dry basis. The figures on "Sirup from same sugar" are on a basis of 11 pounds to the gallon.

A case has never been noted in which by this treatment the sirup produced gives all analytical figures below the minima discussed on page 45 unless the maple sugar has been adulterated by the use of some other sugar.

Trials were also made to determine whether making into a sugar a second time tended to reduce these figures. Samples of sugar sirups were converted into sugar and then redissolved to a sirup of standard density. As shown in Tables I and II, this treatment does not materially change the results.

TABLE III.—*Analysis of sugar sirups converted into sugar and redissolved to sirup.*

| Sirup from first sugaring. | | | | Sirup from second sugaring. | | | |
|---|---|------------------------------|---------------------------|---|---|------------------------------|---------------------------|
| Total ash. | Insoluble ash. | Lead number. | Malic acid value. | Total ash. | Insoluble ash. | Lead number. | Malic acid value. |
| <i>Per cent.</i>
0.78
.87
.83
.77 | <i>Per cent.</i>
0.23
.24
.27
.24 | 1.86
2.14
2.22
1.86 | 0.59
.76
.73
.60 | <i>Per cent.</i>
0.77
.91
.82
.76 | <i>Per cent.</i>
0.23
.24
.28
.25 | 1.88
2.22
2.25
1.87 | 0.60
.78
.74
.62 |

The removal of this precipitated mineral and organic matter, spoken of in commercial manufacture as the refining of the maple sugar, is simply the removal of suspended matter contained in the sugar sirup. As shown by Table III, this does not tend to reduce the analytical figures below the minimum for pure products.

In a later publication ¹ Jones calls attention to the effect of concentration on the percentage of the ash and also malic acid value. As a liquid product is concentrated, its power of holding salts in solution becomes less; hence one expects to find less ash in a more concentrated solution than in one of lower concentration. This is true of maple, as shown in Table IV.

¹ Vt. Agr. Exp. Sta. Bul. 167, p. 466.

TABLE IV.—*Effect of concentration of sirup on ash and malic acid values (Jones).*

| Concentration. | Ash. | | | Malic acid value. |
|---|------------------|------------------|------------------|-------------------|
| | Total. | Soluble. | Insoluble. | |
| | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | |
| Average of 84 sirups having over 34 per cent water..... | 1.02 | 0.45 | 0.57 | 1.00 |
| Average of 42 sirups having from 30 to 34 per cent water..... | .80 | .48 | .32 | .71 |
| Average of 25 sirups having less than 30 per cent water..... | .77 | .49 | .28 | .66 |

¹ Vt. Agr. Exp. Sta. Bul. 167, p. 466.

It is necessary, then, to use care not to concentrate a sample of sirup made from the sugar under examination beyond a certain point, as there might be a precipitation of material which would cause the analyst to believe the sample was adulterated. The data contained in Table V show the likelihood of such an occurrence.

TABLE V.—*Effect of addition of water on ash and malic acid values (Jones).¹*

| Sample No. | Original sirup. | | | | | Water added and heated. | | | | |
|--------------|-----------------|----------------|----------------|----------------|-------------------|-------------------------|----------------|----------------|----------------|-------------------|
| | Moisture. | Ash. | | | Malic acid value. | Moisture. | Ash. | | | Malic acid value. |
| | | Total. | Soluble. | Insoluble. | | | Total. | Soluble. | Insoluble. | |
| | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | |
| 105..... | 30.53 | 0.79 | 0.54 | 0.25 | 0.61 | 39.21 | 0.81 | 0.53 | 0.28 | 0.63 |
| 113..... | 29.99 | .75 | .60 | .25 | .73 | 37.25 | .96 | .55 | .41 | .75 |
| 104..... | 29.46 | .69 | .47 | .22 | .60 | 35.40 | .77 | .43 | .34 | .74 |
| 107..... | 27.90 | .71 | .60 | .21 | .58 | 35.05 | .79 | .54 | .25 | .61 |
| 108..... | 29.64 | .65 | .45 | .20 | .49 | 33.27 | .75 | .52 | .23 | .52 |
| 114..... | 30.69 | .71 | .49 | .22 | .56 | 35.75 | .92 | .65 | .27 | .62 |
| 110..... | 30.94 | .67 | .44 | .23 | .65 | 35.62 | .81 | .56 | .25 | .61 |
| 115..... | 31.04 | .72 | .51 | .21 | .62 | 38.00 | .87 | .61 | .26 | .60 |
| 91..... | 26.75 | .72 | .44 | .28 | .90 | 35.95 | .78 | .51 | .27 | .61 |
| 111..... | 28.29 | .77 | .53 | .24 | .67 | 39.40 | .86 | .60 | .26 | .66 |
| 117..... | 30.70 | .74 | .51 | .23 | .61 | 35.75 | .87 | .53 | .34 | .64 |
| Average..... | 29.63 | .72 | .49 | .23 | .64 | 36.42 | .83 | .55 | .28 | .63 |

¹ Vt. Agr. Exp. Sta. Bul. 167, p. 471.

The original samples were concentrated in each case below the 65 per cent solid content and showed low analytical figures in most cases. Taking these same samples, with the sediment contained therein, and adding water and boiling again to about a 35 per cent moisture content, the analytical figures, with the possible exception of No. 108, where the second concentration is below 35 per cent, are well within the bounds of pure products. Average figures show that changing the concentration from 29.63 per cent water to 36.42 per cent has increased the ash from 0.72 to 0.83 per cent, and the insoluble ash from 0.23 to 0.28 per cent, but has not changed the malic acid content. From this, it is seen that in concentrating the maple sugar sirup for analysis the dry substance of the finished sirup should not be much over 65 to 66 per cent.

COLLECTION OF SAMPLES.

Part of the samples were collected by the authors and part by the official inspectors of the department from makers of maple products. The authenticity of these samples can not then be doubted.

PREPARATION OF SAMPLE.

All chemical examinations were made on a sirup prepared by dissolving 100 grams of the maple sugar in at least 200 cc of water, and boiling the solution down to a consistency of 65 per cent of solid matter. When an undue amount of sediment rendered the solution cloudy, it was boiled until the sirup consisted of about 30 per cent dry matter, after which it was filtered and concentrated to the 65 per cent basis. These solutions were kept at a temperature of 20° C. for two days, during which time the sediment settled, leaving a clear liquid for the determinations.

The physical points ascertained were color of sugar, color of sirup, and taste. The chemical examination consisted in the estimation of sucrose, invert sugar, ash, lead number, and malic acid value, and qualitative test for tannin. A moisture determination was made on a few sugar samples.

COLOR.

Sugar.—The determination on sugar, at best only approximate, was made by comparison with the Dutch standards of color. Eighteen standard sugars, varying from the very dark brown grade of No. 8 to the slightly yellowish white of No. 25, are contained in square glass bottles, which are filled and sealed by an association of sugar brokers in Amsterdam, Holland. As originally prepared, this set of colors was used by the Dutch to grade moist sugars coming from their possessions in the East India Islands, Java, etc. New sets identical in color with the first standards are prepared each year. Although grain maple sugar could be very readily compared, it was necessary to break up the cake or lump sugar and compare the average color of the broken surface with the standards. In most cases this color was practically that of the outside, but in some instances the fracture was almost white.

Sirup.—The set of standard colors employed in the grading of maple-sap sirup ¹ was used in this determination.

TASTE.

The sirups were tasted by two persons, who graded each sample as good, poor, or rank.

MOISTURE IN SIRUP.

The Abbé heatable prism refractometer and the table of Geerlig ² were used for this determination.

¹ U. S. Dept. Agr., Bur. Chem. Bul. 134, p. 15, pl. 1.

² U. S. Dept. Agr., Bur. Chem. Cir. 43, p. 7; U. S. Dept. Agr., Bur. Chem. Bul. 122, p. 169; Jour. Amer. Chem. Soc., 30 (1909), pp. 1443-51.

SUCROSE.

Sucrose was determined from the direct and invert polarization, by the Clerget formula,¹ using the factor 142.66 and hydrochloric acid as the hydrolyst. The results on a number of samples where invertase was the hydrolyst were identical with those obtained with the acid inversion.

INVERT SUGAR.

Munson and Walker's method and tables² were used. The procedure, which is the same as applied to the sap sirups, is given on page 16 of Bureau of Chemistry Bulletin 134.

ASH.

Five grams of the sample were ashed in a platinum dish in an electric oven in the usual way.³ After ashing, a few drops of ammonium carbonate solution were added, the whole evaporated, ignited, and reweighed. The same procedure was followed in the case of insoluble ash. Alkalinity determinations of the soluble and insoluble ash were also made by the usual method.

In valuing maple products, the percentage of total ash is important as well as difficult to ascertain, so that the utmost care is necessary in carrying out this determination. Table VI shows determinations of ash on the same sample: (1) By burning over a free flame at a low heat and again at a red heat; (2) by burning in a muffle at a low and again at a high heat; (3) by burning in an electric oven at ordinary temperature. Following the results in the table are the same determinations after treatment with ammonium carbonate and reignition.

TABLE VI.—*Effect of method of burning on ash content.*

[Not calculated to dry basis.]

| Ex-
peri-
ment
No. | Sample
No. | Burned. | Temperature. | Ash. ⁴ | Ash after
adding
ammonium
carbonate
and heat-
ing. ⁴ |
|-----------------------------|---------------|----------------------|-------------------------|-------------------|--|
| | | | | <i>Per cent.</i> | <i>Per cent.</i> |
| 1 | 8337 | Free flame..... | Low..... | 0.55 | 0.55 |
| | |do..... | High..... | .50 | .54 |
| | | Electric muffle..... | Low..... | .53 | .54 |
| | | Gas muffle..... | Low..... | .54 | .54 |
| | |do..... | High..... | .49 | .54 |
| 2 | 9235 | Free flame..... | Low..... | .51 | .50 |
| | |do..... | High..... | .44 | .51 |
| | | Electric muffle..... | Low..... | .52 | .51 |
| 3 | 8337 | Free flame..... | Low..... | .53 | .53 |
| | |do..... | High ⁵ | .31 | .34 |
| 4 | 8512 | Free flame..... | Low..... | .46 | .46 |
| | |do..... | High ⁵ | .37 | .40 |
| 5 | 8554 | Free flame..... | Low..... | .48 | .48 |
| | |do..... | High ⁵ | .40 | .42 |
| | | Electric muffle..... | Low..... | .47 | .47 |

¹ U. S. Dept. Agr., Bur. Chem. Bul. 107, Rev., p. 41.² U. S. Dept. Agr., Bur. Chem. Bul. 107, Rev., p. 241.³ U. S. Dept. Agr., Bur. Chem. Bul. 134, pp. 16-17.⁴ Average figures.⁵ Temperature much higher than in the first two experiments.

In experiments 1 and 2 the results of burning in the three different ways are the same when the heat is low. When, however, the heat is increased, the percentage drop is 0.05 per cent in experiment 1 and 0.07 per cent in experiment 2, but the addition of ammonium carbonate brings the results back to the normal. In these two cases the extra heating has caused the formation of the oxid from the carbonate, but has not volatilized any of the ash. Repeating experiment 1 with a much greater heat, the ash drops 0.22 per cent and comes back only 0.03 per cent when moistened and reburned. Similar results were obtained in experiments 4 and 5, in both of which the percentage of ash did not come up to the normal by heating with ammonium carbonate. All three show the volatilization of some of the ash.

This all shows the necessity of using the utmost care in carrying out this determination. A very dull red is the highest to which an ash should be heated; then ammonium carbonate should be added and the dish reheated for true results.

LEAD NUMBER.

Two determinations of the lead number were made, using basic lead acetate solution in both. The lead number using normal lead acetate, as described in Bureau of Chemistry Bulletin 134, page 17, was not determined on these samples. The ordinary Winton lead number determination¹ was made and also the modification by S. H. Ross,² which is as follows:

Transfer 25 grams of the sirup to a 100 cc flask, using about 25 cc of distilled water; add 10 cc of potassium sulphate solution (7 grams per liter),³ then 25 cc of lead subacetate solution of the strength specified by Winton. Make up to the mark, shake thoroughly, and allow to stand 3 hours. Filter, rejecting the first portion of the filtrate. Pipette off 10 cc of the clear filtrate into a 250-cc beaker, dilute to 50 cc, add 2 cc of 20 per cent sulphuric acid and 100 cc of 95 per cent alcohol. Let stand overnight, filter off the lead sulphate on an ignited, weighed Gooch crucible, wash with 95 per cent alcohol, dry, ignite at low redness for 3 minutes in a muffle or over a burner, taking care to avoid reducing cone of the flame, and weigh. Run a blank in exactly the same way, substituting 25 grams of a pure cane sugar sirup (66 per cent sucrose content) in place of the sirup to be tested.⁴ Subtract the weight of the lead sulphate, obtained from 10 cc of the sirup test filtrate, from that obtained from 10 cc of the cane sugar sirup blank filtrate. The remainder, expressed in grams and multiplied by 27.325, gives the modified Winton lead number.

In both of these tests the composition of the lead subacetate solution is of the greatest importance, as it greatly influences the lead number. The average results of the basic lead acetate and normal lead acetate lead number taken from the work on sap sirups,⁵ 2.70

¹ U. S. Dept. Agr., Bur. Chem. Bul. 134, p. 17.

² U. S. Dept. Agr., Bur. Chem. Cir. 53.

³ Freshly boiled distilled water should be used throughout.

⁴ Do not use acetic acid in this blank; acidified blank is suggested for use only with original Winton method.

⁵ U. S. Dept. Agr., Bur. Chem. Bul. 134, p. 89.

standing for the basic solution and 0.79 for the normal lead, indicate what may happen when the basicity of the acetate is changed. Browne has called attention to the fact that the basicity of the lead acetate affects the polarization and also that by digestion of varying amounts of neutral lead acetate and litharge at least three well-defined subacetates may be prepared.¹ Changes in treatment as to temperature and length of time of heating and also quantity of the two ingredients may form any one of these or a mixture of two.

An attempt was made to prepare solutions of these different basic lead acetates by varying the amount of lead oxid and the manner of solution as shown in Table VII. After the solutions were made up they were diluted to the same Brix as Winton's solution and a layer of heavy oil placed on top. The alkalinity and amount of lead were determined in each.

TABLE VII.—*Effect of method of preparation on basicity of lead acetate solution.*

| Solution No. | Lead acetate. | Litharge. | Water. | Solution treatment. | Brix reading. | Nitric acid. | Lead. | |
|--------------|---|---------------|------------|-----------------------|-----------------|--------------|--------------------------|-------------------|
| | | | | | | | Cc. N/10 acid per 10 cc. | Grams per 2.5 cc. |
| | <i>Grams.</i> | <i>Grams.</i> | <i>Cc.</i> | | <i>Degrees.</i> | | <i>Per cent.</i> | |
| 1..... | 37.9 | 22.3 | 330 | Stood a week; shaken. | 15.60 | 30.15 | 5.70 | 0.1426 |
| 2..... | 37.9 | 44.6 | 330 | Solution lost. | | | | |
| 3..... | 75.8 | 22.3 | 330 | Stood a week; shaken. | 15.80 | 18.55 | 5.59 | .1398 |
| 4..... | Horne's dry lead subacetate dissolved. | | | | 15.60 | 26.25 | 5.82 | .1454 |
| 5..... | 43.0 | 13.0 | 1,000 | Bolled half hour. | 16.20 | 26.00 | 5.68 | .1421 |
| 6..... | 37.9 | 22.3 | 330 | Do. | 15.77 | 27.50 | 5.80 | .1449 |
| 7..... | 75.8 | 22.3 | 330 | Do. | 15.87 | 19.60 | 5.73 | .1433 |
| 8..... | Neutral lead acetate, saturated solution. | | | | 15.87 | 2.00 | 5.44 | .1359 |

The lead numbers of six samples of maple sirup were determined, using these seven solutions. The results appear in Table VIII.

TABLE VIII.—*Effect of basicity of lead acetate solutions upon the lead number.*

| Sample No. | Lead solution number. | | | | | | |
|--------------|-----------------------|------|------|------|------|------|------|
| | 1 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1..... | 1.49 | 1.13 | 1.29 | 1.31 | 1.40 | 1.13 | 0.29 |
| 2..... | 1.74 | 1.34 | 1.42 | 1.51 | 1.62 | 1.27 | .36 |
| 3..... | 1.79 | 1.41 | 1.57 | 1.56 | 1.72 | 1.39 | .36 |
| 4..... | 1.61 | 1.29 | 1.37 | 1.46 | 1.55 | 1.26 | .34 |
| 5..... | 2.00 | 1.47 | 1.64 | 1.70 | 1.80 | 1.41 | .39 |
| 6..... | 1.86 | 1.40 | 1.58 | 1.63 | 1.78 | 1.47 | .37 |
| Average..... | 1.75 | 1.34 | 1.48 | 1.53 | 1.64 | 1.32 | .35 |

Solution 4, the one usually employed, consisted of 3 parts of lead acetate to 2 parts of lead oxid. Solution 5 was carefully prepared by a method that should give this acetate. The results obtained from solutions 4 and 5 agree fairly well, the difference between the averages being only 0.05. Solutions 1 and 6 give results that are

¹ U. S. Dept. Agr., Bur. Chem. Bul. 122, p. 223.

much above the true lead number, while solutions 3 and 7 are below the true results. Solutions 1 and 6 contain more litharge in proportion to lead acetate than solutions 3 and 7, and likewise show a greater alkalinity. The alkalinity of the solution plays an important part, for when there is practically no alkalinity, as in No. 8, the lead number drops to an average of 0.35.

By preparing the solution of basic lead acetate strictly according to the method outlined in Bureau of Chemistry Bulletin 107, Revised, or in Winton's original method, or by solution of Horne's dry lead subacetate, the results of analysis should be comparable and easily duplicated. The acidity of the sample itself has little effect on the lead number, as shown in Table IX.

TABLE IX.—*Winton lead number of sirup before and after neutralization.*

[Not calculated to dry basis.]

| Sample. | No. 8451. | No. 9235. |
|---------------------------------|-----------|-----------|
| Straight sirup..... | 1.75 | 1.49 |
| Sirup after neutralization..... | 1.78 | 1.56 |

In both samples the lead number was determined on the original sample and again on the same sample after neutralizing the acidity with tenth-normal potassium hydroxid, using phenolphthalein as an indicator. The acidity in one case, No. 8451, equaled 1 cc, in the other, No. 9235, 3 cc, of the tenth-normal potassium hydroxid to 100 cc. The neutralization increased the lead number by only 0.03 and 0.07, respectively.

MALIC ACID VALUE.

The calcium acetate method proposed by Cowles ¹ was used for this determination. In the Bureau's previous work, it had been found that the blanks with calcium acetate were more even and the procedure indicated for this method gave a good precipitate which settled easily. The procedure is as follows:

Weigh 6.7 grams of the sample in a sugar dish, transfer to a 200-cc beaker with 5 cc of water, add 2 cc of a 10 per cent calcium acetate solution, and shake. Stir in 100 cc of 95 per cent alcohol and warm the solution until the precipitate settles, leaving the supernatant liquid clear. Filter off the precipitate and wash with 75 cc of 85 per cent alcohol, dry the filter paper, and ignite in a platinum dish. Add 10 cc of tenth-normal hydrochloric acid and warm gently until all the lime dissolves. Cool and titrate back with tenth-normal sodium hydroxid, using methyl orange as an indicator. One-tenth of the number of cubic centimeters of tenth-normal acid is the malic acid value. Run a blank determination with each set of determinations, using the same amount of reagents, and subtract the result obtained from the malic acid number.

¹ Jour. Amer. Chem. Soc., 30 (1908), p. 1285.

TANNIN REACTION.

A test for the presence of tannin was made in all of the samples by the ferric chlorid reaction as described in Bureau of Chemistry Bulletin 134, page 18.

RESULTS OF ANALYSIS.

The results of analysis of the samples, given in Table X, are arranged by States and counties. The location of the county in the State is shown by the usual symbols, namely, □ center, -□ west of center, ▤ southwest of center, etc. The results of the chemical examination have been calculated to the dry basis for better comparison. Averages have been made for the samples from the individual States, from Canada, and from the United States as a whole, as well as for all of the samples collected.

TABLE X.—*Results of physical and chemical examination of maple-sugar samples.*
[Calculated to dry basis.]

INDIANA.

| Serial number and county or district. | Physical properties. | | Chemical analysis. | | | | | | | | | | Lead number. | | Malic acid value. | Serial number. | |
|---------------------------------------|----------------------|--------|--------------------|---------------------|---------------|-----------------|--------------|--------------|-----------------|--------------|-----------------|-------------|------------------|----------|-------------------|----------------|-------|
| | Color. | | Taste. | Sucrose (Cler-get). | Invert sugar. | Unde-ter-mined. | Total* ash. | Soluble ash. | Insolu-ble ash. | Soluble ash. | Insolu-ble ash. | Alkalinity. | Tannin reaction. | Win-ton. | | | |
| | Sugar. | Sirup. | | | | | | | | | | | | | | | |
| Clinton□: | 16 | 11+ | Fair..... | Per ct. 85.60 | Per ct. 9.53 | Per ct. 3.69 | Per ct. 1.18 | Per ct. 0.83 | Per ct. 0.35 | 2.37 | Cc. 99 | 1.04 | None.... | 3.86 | 4.66 | 1.12 | 8437 |
| | 14 | 14 | do..... | 81.94 | 11.25 | 5.84 | .97 | .66 | .31 | 2.13 | 80 | 1.00 | do..... | 2.82 | 3.68 | .88 | 8438 |
| | 16 | 10 | Good.... | 91.96 | 4.15 | 3.00 | .89 | .64 | .25 | 2.56 | 72 | 1.16 | do..... | 2.50 | 3.23 | .81 | 8439 |
| Hamilton□: | (1) | 10+ | do..... | 92.75 | 2.29 | 3.80 | 1.16 | .70 | .46 | 1.52 | 89 | .78 | do..... | 2.84 | 3.66 | 1.09 | 8443 |
| | (1) | 9 | Fair..... | 92.58 | 3.33 | 3.25 | .84 | .60 | .24 | 2.50 | 74 | 1.21 | do..... | 2.17 | 3.09 | .76 | 8444 |
| | (1) | 9 | do..... | 91.86 | 3.88 | 3.26 | 1.00 | .71 | .29 | 2.45 | 84 | .96 | do..... | 3.05 | 3.71 | 1.02 | 8445 |
| Johnson□: | (1) | 11+ | do..... | 83.00 | 12.29 | 3.74 | .97 | .72 | .25 | 2.88 | 89 | 1.23 | do..... | 2.73 | 3.59 | .89 | 8446 |
| | (1) | 10 | do..... | 90.10 | 5.26 | 3.56 | 1.08 | .77 | .31 | 2.48 | 89 | .93 | do..... | 3.09 | 4.14 | 1.05 | 8458 |
| | (1) | 8 | Good.... | 94.25 | 1.75 | 3.09 | .91 | .68 | .23 | 2.95 | 82 | 1.17 | do..... | 2.52 | 3.01 | .79 | 8459 |
| Lawrence□: | (1) | 7 | do..... | 95.11 | 1.21 | 2.56 | 1.12 | .89 | .23 | 3.87 | 103 | 1.37 | do..... | 2.94 | 3.75 | 1.08 | 8457 |
| Madison□: | 9 | 20+ | Burned. | 86.03 | 12.13 | .26 | 1.58 | .81 | .77 | 1.05 | 96 | .66 | Trace.... | 4.09 | 3.73 | 1.24 | 6394 |
| Marion□: | (1) | 11+ | Fair..... | 92.12 | 3.94 | 2.72 | 1.22 | .69 | .53 | 1.30 | 86 | .68 | None.... | 2.81 | 3.91 | .83 | 8473 |
| | (1) | 13 | do..... | 85.20 | 9.08 | 4.54 | 1.18 | .62 | .56 | 1.11 | 75 | .52 | do..... | 3.55 | 4.20 | 1.18 | 8474 |
| | (1) | 12 | Poor.... | 86.27 | 10.56 | 1.70 | 1.47 | 1.06 | .41 | 2.58 | 108 | 1.14 | do..... | 4.43 | 4.55 | 1.27 | 8475 |
| Morgan□: | 21 | 7+ | Good.... | 92.95 | 2.86 | 3.23 | .96 | .67 | .29 | 2.31 | 93 | 1.41 | do..... | 3.07 | 3.55 | .99 | 8386 |
| Putnam□: | (1) | 11 | Fair..... | 91.97 | 4.28 | 2.55 | 1.20 | .63 | .57 | 1.10 | 79 | .53 | do..... | 3.40 | 4.09 | 1.26 | 8469 |
| | (1) | 10+ | do..... | 93.29 | 3.20 | 2.60 | .91 | .68 | .23 | 2.95 | 90 | 1.30 | do..... | 2.62 | 3.51 | .90 | 8470 |
| | (1) | 9 | do..... | 90.76 | 4.82 | 3.49 | .93 | .62 | .31 | 2.00 | 79 | .85 | do..... | 2.82 | 3.60 | .94 | 8471 |
| 8472..... | (1) | 9 | Good.... | 95.34 | 1.41 | 2.36 | .89 | .66 | .23 | 2.87 | 91 | 1.36 | do..... | 2.39 | 3.21 | .83 | 8472 |
| Average (19)..... | 15 | 10+ | ..... | 90.16 | 5.64 | 2.12 | 1.08 | .72 | .36 | 2.00 | 87 | .93 | ..... | 3.04 | 3.73 | 1.00 | ..... |
| Maximum..... | 21 | 20+ | ..... | 95.34 | 12.29 | 5.84 | 1.58 | 1.06 | .77 | 3.87 | 108 | 1.37 | ..... | 4.43 | 4.66 | 1.27 | ..... |
| Minimum..... | 9 | 7 | ..... | 81.94 | 1.21 | .26 | .84 | .60 | .23 | 1.05 | 72 | .52 | ..... | 2.17 | 3.01 | .76 | ..... |

² Average of 5 determinations.

¹ Undetermined.

TABLE X.—*Results of physical and chemical examination of maple-sugar samples—Continued.*

MAINE.

| Serial number and
county or district. | Physical properties. | | Chemical analysis. | | | | | | | | | | Lead number. | | Maleic
acid
value. | Serial
num-
ber. | | | |
|--|----------------------|--------|--------------------|----------------------------|------------------|-------------------------|---------------|------------------|---------------------|------------------|------------------|---------------------|---------------------|--------------|--------------------------|------------------------|-------|-------|-----|
| | Color. | | Taste. | Sucrose
(Cler-
get). | Invert
sugar. | Unde-
ter-
mined. | Total
ash. | Sol-
ble ash. | Insolu-
ble ash. | Sol-
ble ash. | Alkalinity. | | Tannin
reaction. | Win-
ton. | | | Ross. | | |
| | Sugar. | Sirup. | | | | | | | | | Sol-
ble ash. | Insolu-
ble ash. | | | | | | Cc. | Cc. |
| | | | | | | | | | | | | | | | | | | | |
| Franklin-
6701.....
6702.....
Oxford-
6700.....
7594..... | 16 | 11 | Good..... | Per ct. 96.20 | Per ct. 1.85 | Per ct. 0.99 | Per ct. 0.96 | Per ct. 0.62 | Per ct. 0.34 | 1.82 | 80 | 80 | 1.00 | None.... | 2.38 | 3.64 | 0.99 | 6701 | |
| | 18 | 11 | ...do.... | 95.84 | 1.74 | 1.52 | .90 | .63 | .27 | 2.33 | 79 | 79 | 1.00 | ...do.... | 2.45 | 3.65 | .97 | 6702 | |
| | 12 | 10 | Fair..... | 87.00 | 10.93 | 1.11 | .96 | .65 | .31 | 2.10 | 67 | 88 | .76 | ...do.... | 2.81 | 3.75 | .99 | 6700 | |
| | 14 | 12 | Good..... | 97.39 | 1.72 | .11 | .78 | .55 | .23 | 2.39 | 71 | 31 | 2.29 | ...do.... | 2.08 | 2.57 | .65 | 7594 | |
| Average (4).....
Maximum.....
Minimum..... | 15 | 11 | | 94.11 | 4.06 | .93 | .90 | .61 | .29 | 2.10 | 74 | 69 | 1.07 | | 2.43 | 3.40 | .82 | | |
| | 18 | 12 | Maximum..... | 97.39 | 10.93 | 1.52 | .96 | .65 | .34 | 2.39 | 80 | 88 | 2.29 | ..... | 2.81 | 3.75 | .99 | ..... |  |
| | 12 | 10 | ..... | 87.00 | 1.72 | .11 | .78 | .55 | .23 | 1.82 | 67 | 31 | .76 | ..... | 2.08 | 2.57 | .65 | ..... |  |

MARYLAND.

| | | | | | | | | | | | | | | | | | | |
|--------------|----|-----|-----------|-------|------|------|------|------|------|------|----|-----|------|-------------|------|------|------|-------|
| Garrett's: | 12 | 11 | Far..... | 94.23 | 3.72 | 1.13 | 0.92 | 0.63 | 0.29 | 2.17 | 83 | 70 | 1.19 | None..... | 3.23 | 3.58 | 0.90 | 7506 |
| | 13 | 12 | do..... | 94.70 | 2.20 | 2.18 | .92 | .60 | .32 | 1.88 | 78 | 83 | .94 | do..... | 2.55 | 3.02 | .95 | 7507 |
| | 14 | 12+ | do..... | 94.73 | 3.06 | 1.08 | 1.13 | .77 | .36 | 2.14 | 87 | 105 | .83 | Slight..... | 3.21 | 3.37 | 1.07 | 7508 |
| | 16 | 7 | Good..... | 96.92 | 1.03 | 1.19 | .86 | .61 | .25 | 2.44 | 69 | 56 | 1.23 | None..... | 2.15 | 2.47 | .72 | 7510 |
| | 16 | 13 | do..... | 96.04 | 1.31 | 1.84 | .81 | .44 | .37 | 1.19 | 58 | 81 | .71 | do..... | 2.42 | 2.58 | .78 | 7511 |
| | 15 | 13 | do..... | 94.45 | 2.52 | 2.25 | .78 | .55 | .23 | 2.39 | 57 | 64 | .89 | do..... | 2.14 | 2.32 | .62 | 7512 |
| | 13 | 12 | do..... | 95.81 | 1.96 | 1.26 | .97 | .70 | .27 | 2.59 | 75 | 63 | 1.19 | do..... | 2.47 | 2.98 | .75 | 7513 |
| | 14 | 8 | do..... | 97.49 | 1.28 | .82 | .63 | .29 | .29 | 2.18 | 65 | 68 | .99 | do..... | 2.42 | 2.68 | .79 | 7514 |
| | 17 | 9 | do..... | 96.56 | .97 | 1.56 | .91 | .50 | .41 | 1.22 | 61 | 91 | .67 | do..... | 2.79 | 3.06 | .94 | 7516 |
| | 18 | 11 | Far..... | 97.90 | .65 | .65 | 1.80 | .51 | .29 | 1.76 | 61 | 73 | .83 | do..... | 2.13 | 3.05 | .76 | 7518 |
| | 18 | 13 | do..... | 94.34 | 2.11 | 2.44 | 1.11 | .77 | .34 | 2.26 | 95 | 89 | 1.06 | do..... | 3.19 | 3.78 | 1.08 | 8413 |
| Average (11) | 15 | 11 | do..... | 95.38 | 1.89 | 1.82 | .91 | .60 | .31 | 1.94 | 71 | 77 | .92 | ..... | 2.61 | 2.99 | .85 | ..... |
| Maximum..... | 18 | 13 | do..... | 97.90 | 3.72 | 2.44 | 1.13 | .77 | .41 | 2.59 | 95 | 105 | 1.23 | ..... | 3.23 | 3.78 | 1.08 | ..... |
| Minimum..... | 12 | 7 | do..... | 94.23 | .65 | .41 | .78 | .44 | .23 | 1.19 | 57 | 56 | .67 | ..... | 2.13 | 2.32 | .62 | ..... |

MASSACHUSETTS.

| | | | | | | | | | | | | | | | | | |
|-------------------|----|----|--------------|-------|-------|-------|------|------|------|------|----|----|------|------------|------|------|-------|
| Berkshire □: | 13 | 11 | Good..... | 97.02 | 2.02 | 0.00 | 0.99 | 0.61 | 0.28 | 2.17 | 78 | 79 | 0.98 | Slight.... | 2.92 | 3.46 | 6397 |
| | 13 | 8 | do..... | 83.54 | 14.54 | 1.05 | .87 | .62 | .25 | 2.48 | 67 | 67 | 1.00 | None.... | 2.31 | 3.26 | 6398 |
| Franklin □: | 15 | 8 | Fair..... | 94.09 | 4.59 | .29 | 1.03 | .69 | .34 | 2.03 | 83 | 83 | 1.00 | Slight.... | 3.29 | 3.71 | 6621 |
| | 13 | 8 | do..... | 92.85 | 5.54 | .67 | .94 | .69 | .25 | 2.76 | 87 | 68 | 1.28 | do..... | 3.05 | 3.42 | 6623 |
| Hampden □: | 12 | 10 | do..... | 86.74 | 11.96 | .32 | .98 | .72 | .26 | 2.77 | 84 | 72 | 1.16 | do..... | 2.86 | 3.54 | 6624 |
| | 12 | 11 | do..... | 87.38 | 11.22 | .48 | .92 | .69 | .23 | 3.00 | 84 | 62 | 1.35 | do..... | 2.47 | 3.63 | 6626 |
| | 15 | 13 | Good..... | 97.56 | .73 | .69 | 1.02 | .79 | .23 | 3.43 | 90 | 62 | 1.45 | None.... | 2.70 | 3.49 | 7564 |
| | 15 | 13 | do..... | 98.02 | .79 | .19 | 1.00 | .73 | .27 | 2.70 | 92 | 68 | 1.35 | do..... | 2.17 | 3.25 | 7565 |
| | 15 | 9 | Fair..... | 98.13 | .86 | .09 | .92 | .69 | .23 | 3.00 | 80 | 62 | 1.29 | do..... | 2.41 | 2.70 | 7566 |
| | 15 | 7 | do..... | 98.62 | .27 | .12 | .99 | .75 | .24 | 3.12 | 73 | 66 | 1.10 | do..... | 2.57 | 3.12 | 7567 |
| | 17 | 8 | do..... | 97.12 | 1.00 | .89 | .99 | .64 | .25 | 2.56 | 80 | 64 | 1.25 | do..... | 2.44 | 3.08 | 7568 |
| | 13 | 8 | do..... | 93.34 | 5.71 | .03 | .92 | .69 | .23 | 3.00 | 78 | 61 | 1.28 | do..... | 2.36 | 3.17 | 6508 |
| | 13 | 9 | do..... | 94.89 | 3.79 | .23 | 1.09 | .78 | .31 | 2.51 | 89 | 67 | 1.33 | do..... | 2.81 | 3.33 | 6509 |
| | 13 | 8 | do..... | 85.16 | 13.24 | .58 | 1.02 | .76 | .26 | 2.92 | 82 | 70 | 1.17 | do..... | 3.01 | 3.77 | 6510 |
| Average (14)..... | 14 | 9 | ..... | 93.17 | 5.44 | .41 | .98 | .72 | .26 | 2.77 | 82 | 68 | 1.21 | ..... | 2.67 | 3.35 | ..... |
| | 19 | 12 | Maximum..... | 98.62 | 14.54 | 1.05 | 1.09 | .79 | .34 | 3.43 | 92 | 83 | 1.45 | ..... | 3.29 | 3.77 | ..... |
| Minimum..... | 12 | 7 | ..... | 83.54 | .27 | ..... | .87 | .61 | .23 | 2.03 | 67 | 61 | .98 | ..... | 2.17 | 2.70 | ..... |

MICHIGAN.

| | | | | | | | | | | | | | | | | | |
|-----------|----|-----|-------------|-------|-------|------|------|------|------|------|----|-----|------|------------|------|------|------|
| Barry □: | 14 | 10+ | Fair..... | 93.86 | 1.79 | 3.52 | 0.83 | 0.60 | 0.23 | 2.61 | 74 | 63 | 1.17 | None.... | 2.29 | 3.02 | 8358 |
| | 12 | 12 | do..... | 95.26 | 2.48 | 1.41 | .85 | .62 | .36 | 2.69 | 82 | 58 | 1.41 | Slight.... | 2.35 | 3.08 | 8359 |
| Branch □: | 12 | 12 | do..... | 90.87 | 4.75 | 3.47 | .91 | .55 | .36 | 1.53 | 85 | 91 | .71 | None.... | 2.76 | 3.33 | 8345 |
| | 14 | 10 | Fair..... | 91.86 | 3.85 | 3.25 | .94 | .63 | .31 | 2.03 | 86 | 71 | 1.21 | do..... | 2.42 | 3.44 | 8355 |
| | 12 | 11 | do..... | 91.98 | 5.06 | 2.17 | .79 | .55 | .24 | 2.29 | 66 | 60 | 1.10 | Slight.... | 1.93 | 3.28 | 8356 |
| | 15 | 9 | Good..... | 95.53 | .41 | 3.11 | .95 | .68 | .27 | 2.52 | 81 | 75 | 1.08 | None.... | 2.18 | 2.83 | 8357 |
| Ingham □: | 14 | 12 | do..... | 93.13 | 5.10 | .73 | 1.04 | .78 | .26 | 3.00 | 75 | 90 | .84 | Slight.... | 3.13 | 3.66 | 6457 |
| | 13 | 10 | Fair..... | 89.78 | 8.00 | 1.27 | .95 | .67 | .28 | 2.39 | 74 | 83 | .89 | do..... | 2.98 | 3.72 | 6458 |
| | 13 | 9 | do..... | 82.99 | 15.17 | .99 | .85 | .58 | .27 | 2.15 | 63 | 82 | .77 | do..... | 2.78 | 3.82 | 6459 |
| | 14 | 9 | do..... | 97.12 | 1.08 | .98 | .82 | .46 | .36 | 1.28 | 62 | 90 | .69 | None.... | 2.48 | 3.35 | 7524 |
| | 11 | 15 | Fair..... | 92.04 | 4.51 | 2.50 | .92 | .61 | .31 | 1.97 | 72 | 87 | .83 | do..... | 2.52 | 3.42 | 7526 |
| | 12 | 11 | Good..... | 97.05 | .89 | 1.09 | .97 | .74 | .23 | 3.22 | 86 | 62 | 1.38 | do..... | 2.46 | 3.11 | 7525 |
| Ionia □: | 10 | 15 | Burned..... | 82.38 | 14.34 | 2.18 | 1.10 | .67 | .43 | 1.56 | 68 | 116 | .59 | Trace.... | 3.28 | 4.03 | 6476 |
| | 15 | 10 | Fair..... | 91.64 | 6.38 | 1.06 | .92 | .69 | .23 | 3.00 | 83 | 67 | 1.22 | None.... | 2.60 | 3.43 | 8360 |
| ..... | 14 | 10 | do..... | 94.75 | 2.23 | 2.18 | .84 | .62 | .22 | 2.82 | 77 | 56 | 1.38 | do..... | 2.15 | 3.14 | 8361 |

TABLE X.—Results of physical and chemical examination of maple-sugar samples—Continued.

MICHIGAN—Continued.

| Serial number and county or district. | Physical properties. | | Chemical analysis. | | | | | | | | | | Lead number. | | Malic acid value. | Serial number. | | | |
|---------------------------------------|----------------------|--------|--------------------|--------------------|---------------|---------------|------------|--------------|----------------|--------------|--------------|----------------|------------------|-------------|-------------------|----------------|--------------|-----|-----|
| | Color. | | Taste. | Sucrose (Clerget). | Invert sugar. | Undetermined. | Total ash. | Soluble ash. | Insoluble ash. | Soluble ash. | Alkalinity. | | Tannin reaction. | Win-ton. | | | | | |
| | Sugar. | Sirup. | | | | | | | | | Soluble ash. | Insoluble ash. | | | | | Soluble ash. | Cc. | Cc. |
| | | | | | | | | | | | | | | | | | | | |
| Kent □: | 13 | 10 | Fair..... | 95.05 | 3.57 | .46 | .92 | .61 | .31 | 1.97 | 75 | 92 | 0.81 | Slight..... | 3.11 | 3.72 | 6499 | | |
| | 13 | 13 | do..... | 91.45 | 4.14 | 3.45 | .96 | .61 | .35 | 1.74 | 70 | 95 | .73 | do..... | 2.72 | 3.59 | 90 | | |
| | 12 | 13+ | do..... | 8362 | 8361 | 8361 | 831 | .58 | .23 | 2.52 | 72 | 61 | 1.18 | do..... | 2.18 | 3.03 | 8362 | | |
| | 13 | 13 | do..... | 8365 | 8365 | 2.06 | .77 | .54 | .23 | 2.35 | 65 | 57 | 1.14 | do..... | 1.96 | 2.92 | 61 | | |
| | 13 | 10+ | do..... | 8366 | 8366 | 1.18 | .93 | .70 | .23 | 3.04 | 74 | 56 | 1.32 | None.... | 1.91 | 2.54 | 60 | | |
| Lenore □: | 14 | 9 | do..... | 94.80 | 7.94 | 2.49 | .77 | .54 | .23 | 2.35 | 72 | 60 | 1.20 | do..... | 2.13 | 2.89 | 1.15 | | |
| 8354..... | 12 | 10 | do..... | 85.45 | 10.69 | 2.83 | 1.03 | .67 | .36 | 1.87 | 74 | 102 | .72 | Slight..... | 3.29 | 4.18 | 1.08 | | |
| Ottawa □: | 11 | 11+ | do..... | 93.26 | 4.08 | 1.89 | .79 | .53 | .26 | 2.03 | 67 | 83 | .81 | do..... | 2.42 | 3.13 | .78 | | |
| 8363..... | 11 | 11 | do..... | 92.00 | 4.03 | 2.47 | .90 | .62 | .28 | 2.21 | 73 | 76 | .96 | do..... | 2.52 | 3.33 | .83 | | |
| Average (23)..... | 15 | 15 | Maximum..... | 97.12 | 15.17 | 3.52 | 1.10 | .78 | .43 | 3.22 | 86 | 116 | 1.41 | do..... | 3.29 | 4.18 | 1.15 | | |
| Minimum..... | 11 | 9 | do..... | 82.38 | .41 | .46 | .77 | .46 | .22 | 1.28 | 62 | 56 | .59 | do..... | 1.91 | 2.54 | .60 | | |

NEW HAMPSHIRE.

| | | | | | | | | | | | | | | | | | |
|-------------|----|----|-----------|-------|-------|------|------|------|------|------|----|----|------|------------|------|------|------|
| Cheshire □: | 14 | 9 | Good..... | 97.43 | 1.10 | 0.48 | 0.99 | 0.71 | 0.28 | 2.52 | 80 | 77 | 1.04 | None..... | 2.55 | 3.35 | 7581 |
| 7581..... | 13 | 11 | Poor..... | 91.96 | 6.15 | .91 | .98 | .70 | .28 | 2.50 | 78 | 81 | .97 | Slight.... | 2.42 | 3.36 | 7582 |
| 7582..... | 16 | 10 | Fair..... | 94.40 | 1.36 | 3.43 | .81 | .56 | .25 | 2.26 | 73 | 61 | 1.19 | None.... | 1.97 | 2.76 | 8432 |
| 8432..... | 16 | 9 | do..... | 94.92 | 1.09 | 2.55 | .84 | .59 | .25 | 2.36 | 76 | 58 | 1.31 | do..... | 2.17 | 3.00 | 8433 |
| 8433..... | 13 | 13 | do..... | 83.47 | 2.10 | 3.63 | .80 | .47 | .33 | 1.42 | 64 | 83 | .77 | do..... | 1.91 | 2.65 | 8434 |
| Grafton □: | 13 | 9 | do..... | 79.69 | 16.77 | 2.70 | .84 | .48 | .36 | 1.33 | 66 | 81 | .81 | do..... | 2.43 | 4.32 | 6678 |
| 6678..... | 12 | 9 | do..... | 60.81 | 27.21 | 2.12 | .86 | .48 | .38 | 1.27 | 69 | 91 | .75 | do..... | 2.81 | 3.78 | 6679 |
| 6679..... | 13 | 9 | do..... | 90.83 | 7.43 | .86 | .88 | .52 | .36 | 1.45 | 75 | 88 | .85 | do..... | 2.44 | 3.49 | 6684 |
| 6684..... | 11 | 13 | Burned. | 91.57 | 6.08 | 1.41 | .94 | .51 | .43 | 1.18 | 63 | 97 | .65 | Trace.... | 2.49 | 3.82 | 6685 |

| | | | | | | | | | | | | | | | | |
|-------------------|-----|----|-----------|-------|-------|------|------|-----|------|----|-----|------|-----------|------|------|-------|
| Hillsborough □: | 13 | 11 | Good.... | 93.13 | 4.29 | 1.65 | .83 | .67 | 2.57 | 83 | 62 | 1.34 | None.... | 2.41 | 3.35 | 6662 |
| 6662..... | 13 | 11 | ...do.... | 92.65 | 5.70 | .52 | 1.13 | .74 | 1.89 | 87 | 104 | .83 | Slight... | 3.48 | 4.27 | 6663 |
| Sullivan □: | 14 | 8 | Fair.... | 84.65 | 12.69 | 1.73 | .93 | .64 | 2.21 | 81 | 81 | 1.00 | None.... | 2.97 | 3.94 | 6677 |
| 6677..... | 14 | 8 | Fair.... | 84.65 | 12.69 | 1.73 | .93 | .64 | 2.21 | 81 | 81 | 1.00 | None.... | 2.97 | 3.94 | 6677 |
| Average (12)..... | 13+ | 10 | Good.... | 89.54 | 7.71 | 1.84 | .91 | .59 | 1.84 | 75 | 80 | .94 | ..... | 2.40 | 3.50 | ..... |
| Maximum..... | 16 | 13 | ..... | 97.43 | 27.21 | 3.63 | 1.13 | .74 | 2.57 | 87 | 104 | 1.34 | ..... | 3.48 | 4.32 | ..... |
| Minimum..... | 11 | 8 | ..... | 69.81 | 1.10 | .48 | .80 | .48 | 1.18 | 63 | 61 | .65 | ..... | 1.91 | 2.65 | ..... |

NEW YORK.

| | | | | | | | | | | | | | | | | |
|---------------|----|-----|----------|-------|-------|------|------|------|------|----|----|------|-----------|------|------|------|
| Allegany □: | 14 | 8 | Fair.... | 84.46 | 11.70 | 3.00 | 0.84 | 0.48 | 0.36 | 60 | 66 | 0.90 | None.... | 2.17 | 3.22 | 6545 |
| 6545..... | 14 | 8 | Fair.... | 84.46 | 11.70 | 3.00 | 0.84 | 0.48 | 0.36 | 60 | 66 | 0.90 | None.... | 2.17 | 3.22 | 6545 |
| 6546..... | 16 | 12 | do.... | 94.70 | 3.88 | .45 | .97 | .64 | .33 | 58 | 79 | .73 | Slight... | 2.71 | 3.28 | 6546 |
| 7546..... | 13 | 10 | Good.... | 97.20 | 1.15 | .75 | .90 | .67 | .23 | 86 | 57 | 1.56 | None.... | 2.15 | 3.46 | 7546 |
| 7547..... | 11 | 12 | do.... | 96.08 | 2.03 | .04 | .85 | .61 | .24 | 81 | 55 | 1.39 | do.... | 2.37 | 3.05 | 7547 |
| 7548..... | 16 | 7 | do.... | 97.75 | .34 | 1.06 | .85 | .61 | .24 | 83 | 60 | 1.35 | do.... | 2.52 | 3.11 | 7548 |
| 7549..... | 15 | 8 | do.... | 97.54 | .51 | 1.09 | .86 | .63 | .24 | 81 | 53 | 1.36 | do.... | 2.45 | 3.08 | 7549 |
| 7550..... | 14 | 10 | do.... | 96.20 | 2.13 | .76 | .91 | .67 | .24 | 87 | 55 | 1.31 | do.... | 2.67 | 3.11 | 7550 |
| 7551..... | 13 | 11 | do.... | 96.08 | 1.50 | 1.54 | .88 | .63 | .25 | 87 | 65 | 1.34 | do.... | 2.61 | 3.03 | 7551 |
| 7552..... | 15 | 8 | do.... | 98.03 | .29 | .68 | 1.00 | .73 | .27 | 88 | 54 | 1.63 | do.... | 2.36 | 3.03 | 7552 |
| 8324..... | 18 | 8 | do.... | 95.50 | 1.25 | 2.38 | .87 | .55 | .32 | 71 | 72 | .98 | do.... | 2.18 | 2.75 | 8324 |
| 8325..... | 18 | 9 | do.... | 95.06 | 1.14 | 3.01 | .79 | .50 | .29 | 67 | 73 | .92 | do.... | 2.05 | 2.74 | 8325 |
| Chautauque □: | 12 | 10 | do.... | 97.88 | 1.07 | .10 | .95 | .69 | .26 | 58 | 75 | .77 | do.... | 2.45 | 2.77 | 6547 |
| 6547..... | 12 | 11 | Fair.... | 97.12 | 1.78 | .22 | .88 | .61 | .27 | 65 | 78 | .88 | Slight... | 2.41 | 2.79 | 6601 |
| 6601..... | 13 | 8 | Good.... | 97.07 | 1.47 | .61 | .85 | .60 | .25 | 68 | 74 | .92 | None.... | 2.18 | 2.72 | 6602 |
| Chautauque □: | 13 | 9 | Fair.... | 90.47 | 7.72 | 1.84 | .83 | .61 | .32 | 53 | 82 | .64 | do.... | 2.61 | 3.18 | 6548 |
| 6548..... | 13 | 9 | Fair.... | 90.47 | 7.72 | 1.84 | .83 | .61 | .32 | 53 | 82 | .64 | do.... | 2.61 | 3.18 | 6548 |
| 6549..... | 8 | 13 | do.... | 84.48 | 12.70 | .98 | .98 | .58 | 1.45 | 52 | 91 | .57 | Slight... | 2.74 | 3.37 | 6549 |
| 6550..... | 11 | 10+ | Good.... | 96.24 | 2.64 | .10 | 1.02 | .70 | .32 | 83 | 80 | 1.04 | do.... | 2.73 | 3.22 | 6550 |
| 6552..... | 13 | 8 | do.... | 97.70 | 1.54 | .04 | .80 | .55 | .25 | 69 | 61 | 1.13 | None.... | 2.78 | 3.11 | 6552 |
| 6553..... | 13 | 8 | do.... | 95.80 | 2.80 | .39 | 1.01 | .75 | .26 | 77 | 77 | 1.00 | do.... | 2.46 | 3.12 | 6553 |
| 7553..... | 16 | 10 | do.... | 98.02 | .71 | .49 | .78 | .54 | .24 | 69 | 60 | 1.15 | do.... | 2.36 | 2.87 | 7553 |
| 7554..... | 14 | 8 | do.... | 98.00 | .31 | .90 | .79 | .56 | .23 | 78 | 70 | 1.56 | do.... | 2.36 | 2.57 | 7554 |
| 7555..... | 12 | 11 | do.... | 96.16 | 1.96 | 1.02 | .86 | .55 | .31 | 64 | 70 | .91 | do.... | 2.26 | 2.77 | 7555 |
| 7556..... | 12 | 14 | do.... | 96.42 | .84 | 1.78 | .96 | .49 | .47 | 66 | 96 | .68 | do.... | 2.20 | 3.00 | 7556 |
| 7557..... | 13 | 9 | do.... | 97.80 | .96 | 1.16 | 1.08 | .81 | .27 | 73 | 61 | 1.19 | do.... | 2.64 | 2.98 | 7557 |
| 8328..... | 13 | 7 | do.... | 96.20 | 1.01 | 2.01 | .78 | .53 | .25 | 75 | 70 | 1.07 | do.... | 2.23 | 2.98 | 8328 |
| Chenango □: | 14 | 8 | Good.... | 84.89 | 13.20 | .99 | .92 | .67 | .25 | 77 | 74 | 1.04 | do.... | 2.74 | 3.58 | 6486 |
| 6486..... | 13 | 9+ | Fair.... | 94.81 | 3.97 | .23 | .99 | .67 | .32 | 76 | 83 | .92 | do.... | 2.86 | 3.42 | 6487 |
| 6487..... | 13 | 9+ | Fair.... | 94.81 | 3.97 | .23 | .99 | .67 | .32 | 76 | 83 | .92 | do.... | 2.86 | 3.42 | 6487 |
| Cortland □: | 14 | 9 | do.... | 97.34 | 1.56 | .27 | .83 | .60 | .23 | 79 | 58 | 1.36 | do.... | 2.26 | 2.73 | 6472 |
| 6472..... | 14 | 9 | do.... | 97.34 | 1.56 | .27 | .83 | .60 | .23 | 79 | 58 | 1.36 | do.... | 2.26 | 2.73 | 6472 |
| 6479..... | 12 | 9 | do.... | 93.12 | 5.34 | .57 | .97 | .62 | .35 | 74 | 86 | .86 | Slight... | 2.97 | 3.53 | 6479 |
| 6485..... | 11 | 11 | Good.... | 97.53 | 1.00 | .44 | 1.03 | .75 | .28 | 85 | 74 | 1.15 | do.... | 2.69 | 3.17 | 6485 |
| 6554..... | 13 | 10 | Fair.... | 96.46 | 2.07 | .39 | 1.08 | .84 | .24 | 79 | 71 | 1.11 | do.... | 2.67 | 3.11 | 6554 |

¹ Average of 22 determinations.

TABLE X.—*Results of physical and chemical examination of maple-sugar samples—Continued.*
NEW YORK—Continued.

| Serial number and county or district. | Physical properties. | | Chemical analysis. | | | | | | | | | | Lead number. | | Maltic acid value. | Serial number. | | |
|---------------------------------------|----------------------|--------|--------------------|--------------------|---------------|---------------|--------------|--------------|----------------|--------------|--------------|----------------|------------------|-------------|--------------------|----------------|-------|----------------|
| | Color. | | Taste. | Sucrose (Clerget). | Invert sugar. | Undetermined. | Total ash. | Soluble ash. | Insoluble ash. | Soluble ash. | Alkalinity. | | Tannin reaction. | Wintou. | | | | |
| | Sugar. | Sirup. | | | | | | | | | Soluble ash. | Insoluble ash. | | | | | Cc. | Insoluble ash. | Soluble ash. |
| Courtland—Continued. | 15 | 7 | Fair..... | Per ct. 94.24 | Per ct. 4.06 | Per ct. 0.91 | Per ct. 0.79 | Per ct. 0.53 | Per ct. 0.26 | 2.03 | Cc. 52 | Cc. 68 | 0.77 | Slight..... | 2.21 | 2.88 | 6555 | |
| | 15 | 9 | do..... | 97.61 | 1.02 | 0.58 | 0.79 | 0.51 | 0.28 | 1.82 | 49 | 58 | 0.85 | do..... | 1.86 | 2.89 | 7559 | |
| | 12 | 9 | Good..... | 96.64 | 77 | 1.83 | 0.78 | 0.51 | 0.27 | 1.89 | 64 | 59 | 1.08 | do..... | 1.87 | 2.31 | 7560 | |
| | 12 | 11 | Fair..... | 97.48 | 83 | 0.88 | 0.81 | 0.58 | 0.23 | 2.52 | 76 | 50 | 1.32 | do..... | 2.37 | 2.45 | 7561 | |
| | 17 | 7 | Good..... | 98.01 | 90 | 0.11 | 0.98 | 0.75 | 0.23 | 3.21 | 68 | 57 | 1.19 | do..... | 2.14 | 2.65 | 7562 | |
| | 17 | 7 | Fair..... | 97.46 | 1.22 | 0.38 | 0.94 | 0.66 | 0.28 | 2.36 | 73 | 93 | 0.78 | do..... | 2.38 | 3.48 | 6636 | |
| | 14 | 8 | do..... | 97.63 | 0.92 | 0.53 | 0.92 | 0.68 | 0.24 | 2.85 | 71 | 85 | 0.83 | do..... | 2.11 | 3.28 | 6638 | |
| Delaware □: | 13 | 13 | Good..... | 98.14 | 1.14 | 1.16 | 0.91 | 0.65 | 0.26 | 2.51 | 71 | 86 | 1.39 | Trace..... | 2.34 | 3.23 | 95 | |
| | 13 | 13+ | Burned..... | 94.08 | 3.44 | 1.16 | 1.32 | 1.06 | 0.26 | 4.07 | 123 | 80 | 1.39 | do..... | 3.04 | 3.87 | 6639 | |
| | 12 | 13 | do..... | 95.20 | 2.76 | 1.13 | 0.91 | 0.63 | 0.28 | 2.25 | 71 | 92 | 0.77 | None..... | 2.60 | 3.48 | 6641 | |
| | 13 | 11 | Fair..... | 96.85 | 1.81 | 0.42 | 0.92 | 0.63 | 0.29 | 2.20 | 70 | 92 | 0.76 | Trace..... | 2.44 | 3.26 | 6643 | |
| | 12 | 11 | do..... | 94.00 | 4.79 | 0.80 | 0.81 | 0.51 | 0.29 | 1.76 | 58 | 68 | 0.85 | do..... | 1.89 | 2.67 | 6644 | |
| | 13 | 10 | Good..... | 98.22 | 0.97 | 0.05 | 0.86 | 0.49 | 0.37 | 1.32 | 66 | 85 | 0.77 | None..... | 2.23 | 2.74 | 6644 | |
| | 14 | 10 | do..... | 98.16 | 1.05 | +1.4 | 0.93 | 0.51 | 0.42 | 1.21 | 66 | 104 | 0.63 | do..... | 2.75 | 3.55 | 7583 | |
| | 14 | 8 | do..... | 98.05 | 1.48 | +1.52 | 0.95 | 0.56 | 0.39 | 1.44 | 66 | 88 | 0.75 | do..... | 2.28 | 2.97 | 7584 | |
| | Lewis □: | 12 | 16 | Fair..... | 94.56 | 3.84 | 0.60 | 1.00 | 0.58 | 0.42 | 1.38 | 56 | 106 | 0.52 | Good..... | (1) | (1) | 6603 |
| | | 16 | 10 | do..... | 98.09 | 0.55 | 0.48 | 0.88 | 0.55 | 0.33 | 1.67 | 61 | 86 | 0.71 | Slight..... | 2.35 | 2.80 | 6604 |
| 13 | | 12 | Good..... | 98.52 | ..... | 0.60 | 0.88 | 0.49 | 0.39 | 1.26 | 62 | 80 | 0.77 | do..... | 2.07 | 2.47 | 6607 | |
| 16 | | 11 | do..... | 98.07 | ..... | 0.56 | 0.87 | 0.49 | 0.48 | 1.29 | 58 | 93 | 0.62 | do..... | 2.10 | 2.50 | 84 | |
| 14 | | 12 | do..... | 98.07 | ..... | 0.56 | 0.87 | 0.49 | 0.48 | 1.29 | 58 | 93 | 0.62 | do..... | 2.06 | 2.33 | 6608 | |
| 16 | | 10 | do..... | 98.24 | 1.43 | 0.26 | 1.01 | 0.77 | 0.24 | 3.21 | 72 | 64 | 1.13 | None..... | 2.10 | 2.89 | 7575 | |
| 15 | | 8 | do..... | 98.28 | 1.43 | +0.95 | 1.24 | 0.64 | 0.60 | 1.07 | 80 | 52 | 1.54 | do..... | 2.10 | 2.88 | 7576 | |
| 16 | | 8 | do..... | 98.28 | 1.43 | +0.95 | 1.24 | 0.64 | 0.60 | 1.07 | 69 | 60 | 1.54 | do..... | 2.15 | 2.88 | 7577 | |
| 16 | | 8 | do..... | 96.87 | 1.89 | 0.29 | 1.95 | 0.67 | 0.28 | 2.39 | 74 | 71 | 1.04 | do..... | 2.61 | 3.04 | 7578 | |
| 13 | | 9 | do..... | 96.57 | 2.26 | 0.09 | 1.08 | 0.78 | 0.30 | 2.60 | 82 | 76 | 1.08 | do..... | 3.04 | 3.43 | 7579 | |
| 7580. | 14 | 10 | do..... | 96.87 | 1.79 | 0.34 | 1.60 | 0.70 | 0.30 | 2.34 | 85 | 85 | 1.00 | do..... | 2.59 | 3.96 | 7580 | |
| Average (56). | 14 | 10 | ..... | 96.04 | 2.33 | 0.71 | 0.92 | 0.62 | 0.30 | 2.07 | 72 | 73 | 0.99 | ..... | 2.42 | 3.05 | ..... |  |
| | 18 | 16 | Maximum..... | 98.52 | 13.20 | 3.01 | 1.32 | 1.06 | 0.60 | 4.07 | 123 | 106 | 1.03 | ..... | 3.64 | 3.96 | ..... |  |
| Minimum..... | 8 | 7 | ..... | 84.46 | 0.29 | 0.04 | 0.78 | 0.48 | 0.23 | 1.04 | 49 | 50 | 0.52 | ..... | 1.86 | 2.31 | ..... |  |

OHIO.

| | | | | | | | | | | | | | | | | | | |
|---------------------------|----|----|-------------|-------|-------|------|------|------|------|------|----|-----|------|-------------|------|------|-------|-------|
| Allen □:
7572..... | 12 | 9 | Good.... | 96.20 | 1.84 | 1.04 | 0.92 | 0.09 | 0.23 | 3.00 | 78 | 61 | 1.28 | None.... | 2.41 | 3.00 | 0.78 | 7572 |
| Champaign □:
6313..... | 14 | 9 | Fair.... | 85.51 | 10.51 | 3.01 | .97 | .65 | .82 | 2.03 | 86 | 92 | .93 |do.... | 3.53 | 3.02 | 1.14 | 6313 |
| 6321..... | 12 | 8 |do.... | 98.38 | .68 | .05 | .99 | .72 | .27 | 2.66 | 62 | 56 | 1.11 |do.... | 2.17 | 2.54 | .74 | 6321 |
| Cuyahoga □:
6966..... | 14 | 8 | Good.... | 87.95 | 9.07 | 1.99 | .99 | .68 | .31 | 2.19 | 72 | 79 | .91 |do.... | 2.77 | 3.74 | 1.07 | 6966 |
| 6967..... | 12 | 9 |do.... | 84.84 | 13.10 | 1.19 | .87 | .64 | .23 | 2.78 | 71 | 81 | .87 |do.... | 2.50 | 3.48 | .88 | 6967 |
| Gauga □:
6370..... | 14 | 12 | Fair.... | 91.49 | 5.60 | 1.93 | .98 | .67 | .31 | 2.16 | 73 | 78 | .93 |do.... | 3.10 | 3.73 | 1.03 | 6370 |
| 6373..... | 16 | 8 |do.... | 83.34 | 14.08 | 1.80 | .78 | .42 | .36 | 1.17 | 50 | 76 | .66 |do.... | 2.16 | 2.22 | .83 | 6373 |
| 6374..... | 13 | 7 |do.... | 83.31 | 10.93 | 4.94 | .83 | .43 | .39 | 1.10 | 49 | 86 | .57 |do.... | 2.23 | 2.25 | .78 | 6374 |
| 6378..... | 11 | 10 |do.... | 84.85 | 11.93 | 2.33 | .92 | .47 | .45 | 1.03 | 63 | 96 | .63 |do.... | 2.60 | 2.72 | .92 | 6378 |
| 6968..... | 14 | 13 | Poor.... | 80.46 | 17.33 | 1.22 | .99 | .61 | .38 | 1.61 | 59 | 104 | .56 |do.... | 2.94 | 3.95 | 1.08 | 6968 |
| 6969..... | 13 | 12 | Fair.... | 78.94 | 18.09 | 2.09 | .84 | .61 | .23 | 2.73 | 58 | 67 | .86 |do.... | 2.66 | 3.63 | .86 | 6969 |
| 8347..... | 16 | 9 | Fair.... | 95.88 | 1.42 | 1.87 | .83 | .60 | .23 | 2.60 | 70 | 61 | 1.15 |do.... | 2.06 | 2.85 | .71 | 8347 |
| 8348..... | 13 | 9 | Good.... | 94.13 | 2.11 | 2.96 | .80 | .56 | .24 | 2.33 | 65 | 71 | .81 |do.... | 2.13 | 2.96 | .67 | 8348 |
| 8349..... | 18 | 7+ |do.... | 96.00 | .68 | 2.55 | .77 | .55 | .22 | 2.50 | 73 | 43 | 1.70 |do.... | 1.86 | 2.58 | .92 | 8349 |
| 8351..... | 16 | 7 |do.... | 96.53 | .33 | 3.28 | .76 | .53 | .23 | 2.30 | 76 | 55 | 1.38 |do.... | 1.85 | 2.45 | .78 | 8351 |
| 8447..... | 17 | 6 | Fair.... | 95.02 | .21 | 3.28 | .89 | .56 | .33 | 1.70 | 69 | 90 | .77 |do.... | 2.50 | 3.13 | 1.01 | 8447 |
| 8448..... | 14 | 8 |do.... | 94.64 | .98 | 3.43 | .95 | .62 | .33 | 1.88 | 77 | 86 | .89 |do.... | 2.61 | 3.31 | 1.00 | 8448 |
| 8449..... | 14 | 11 |do.... | 93.61 | 1.56 | 3.78 | 1.05 | .62 | .43 | 1.44 | 79 | 102 | .77 |do.... | 2.93 | 3.86 | 1.07 | 8449 |
| 8450..... | 7 | 7 | Good.... | 95.04 | .26 | 3.80 | .90 | .58 | .32 | 1.81 | 67 | 83 | .80 |do.... | 2.28 | 2.95 | .61 | 8450 |
| Logan □:
6314..... | 14 | 8 | Fair.... | 95.06 | 2.64 | 1.37 | .93 | .64 | .29 | 2.21 | 79 | 82 | .96 |do.... | 3.10 | 3.35 | 1.01 | 6314 |
| 6315..... | 12 | 12 |do.... | 93.50 | 2.74 | 2.59 | 1.17 | .82 | .35 | 2.34 | 98 | 105 | .93 | Trace.... | 3.61 | 3.57 | 1.14 | 6315 |
| 6316..... | 8 | 16 |do.... | 94.45 | 1.77 | 2.66 | 1.12 | .78 | .34 | 2.29 | 91 | 109 | .83 |do.... | 3.45 | 3.56 | 1.11 | 6316 |
| 6317..... | 11 | 12 |do.... | 95.25 | 1.94 | 1.89 | .92 | .58 | .34 | 1.71 | 75 | 92 | .81 |do.... | 3.07 | 3.36 | 1.02 | 6317 |
| 6318..... | 13 | 10 | Poor.... | 93.25 | 3.04 | 2.64 | 1.07 | .68 | .39 | 1.74 | 83 | 107 | .79 | None.... | 3.47 | 3.32 | ..... | 6318 |
| 6319..... | 16 | 12 | Fair.... | 93.26 | 1.90 | 2.73 | 1.11 | .68 | .37 | 2.58 | 97 | 91 | 1.06 |do.... | 3.62 | 3.95 | 1.16 | 6319 |
| 6320..... | 14 | 12 |do.... | 88.22 | 8.78 | 1.77 | 1.23 | .86 | .37 | 2.32 | 93 | 101 | .92 | Trace.... | 4.24 | 4.67 | 1.31 | 6320 |
| Medina □:
7570..... | 13 | 11 | Good.... | 96.00 | 1.74 | 1.33 | .93 | .59 | .34 | 1.73 | 70 | 71 | .98 | None.... | 2.37 | 3.21 | .83 | 7570 |
| 7571..... | 14 | 10 |do.... | 95.54 | 2.76 | .87 | .83 | .56 | .27 | 2.07 | 69 | 59 | 1.17 |do.... | 2.24 | 3.10 | .77 | 7571 |
| Morrow □:
7573..... | 12 | 11 | Fair.... | 95.88 | 1.90 | 1.33 | .89 | .64 | .25 | 2.56 | 78 | 65 | 1.20 |do.... | 2.04 | 2.75 | .76 | 7573 |
| 7574..... | 9 | 20 |do.... | 57.04 | 30.02 | 5.72 | 1.42 | 1.04 | .38 | 2.74 | 97 | 80 | 1.21 | Trace.... | 3.98 | 4.27 | .71 | 7574 |
| Trumbull □:
6718..... | 14 | 8 | Poor.... | 75.12 | 22.16 | 1.82 | .90 | .67 | .23 | 2.91 | 75 | 70 | 1.07 | None.... | 2.67 | 3.88 | .93 | 6718 |
| Average (31)..... | 13 | 10 |do.... | 89.98 | 6.52 | 2.55 | .95 | .64 | .31 | 2.06 | 74 | 81 | .91 |do.... | 2.74 | 3.29 | .92 | ..... |
| Maximum..... | 18 | 20 |do.... | 98.38 | 30.02 | 5.72 | 1.23 | 1.04 | .45 | 3.00 | 98 | 109 | 1.70 |do.... | 1.85 | 4.24 | 1.16 | ..... |
| Minimum..... | 8 | 7 |do.... | 57.04 | .21 | .05 | .76 | .42 | .22 | 1.03 | 49 | 43 | .56 |do.... | 1.85 | 2.22 | .61 | ..... |

³ Average of 29 determinations.

² Average of 55 determinations.

¹ Undetermined.

TABLE X.—*Results of physical and chemical examination of maple-sugar samples*—Continued.
PENNSYLVANIA.

| Serial number and county or district. | Physical properties. | | Chemical analysis. | | | | | | | | | | Lead number. | | Malic acid value. | Serial number. |
|---------------------------------------|----------------------|--------|--------------------|--------------------|---------------|---------------|--------------|--------------|----------------|--------------|----------------|------------------|--------------|-------|-------------------|----------------|
| | Color. | | Taste. | Sucrose (Clerget). | Invert sugar. | Undetermined. | Total ash. | Soluble ash. | Insoluble ash. | Alkalinity. | | Tannin reaction. | Win-ton. | Ross. | | |
| | Sugar. | Sirup. | | | | | | | | Soluble ash. | Insoluble ash. | | | | | |
| Bradford: | 14 | 16 | Good | Per ct. 93.60 | Per ct. 4.16 | Per ct. 1.01 | Per ct. 1.23 | Per ct. 0.69 | Per ct. 0.54 | Cc. 68 | Cc. 135 | Trace | 3.90 | 4.23 | 1.23 | 6873 |
| | 15 | 9 | Fair | Per ct. 91.56 | Per ct. 5.89 | Per ct. 1.01 | Per ct. 1.14 | Per ct. 0.75 | Per ct. 0.39 | 92 | 89 | None | 2.16 | 4.53 | 1.24 | 6874 |
| | 13 | 9 | Good | Per ct. 97.97 | Per ct. 8.82 | Per ct. 0.28 | Per ct. 0.93 | Per ct. 0.66 | Per ct. 0.27 | 73 | 115 | do. | 2.75 | 2.90 | 0.82 | 6875 |
| | 13 | 10 | do. | Per ct. 89.08 | Per ct. 10.30 | Per ct. 0.16 | Per ct. 0.78 | Per ct. 0.52 | Per ct. 0.26 | 52 | 55 | do. | 1.91 | 2.66 | 0.69 | 6876 |
| | 12 | 12 | do. | Per ct. 87.92 | Per ct. 7.50 | Per ct. 0.98 | Per ct. 1.03 | Per ct. 0.72 | Per ct. 0.26 | 69 | 90 | do. | 3.04 | 3.56 | 0.90 | 6877 |
| | 16 | 8 | do. | Per ct. 96.89 | Per ct. 7.78 | Per ct. 1.30 | Per ct. 1.03 | Per ct. 0.71 | Per ct. 0.32 | 68 | 98 | do. | 2.77 | 2.86 | 0.86 | 6884 |
| Lancaster: | 16 | 16 | Fair | Per ct. 93.40 | Per ct. 5.16 | Per ct. 0.19 | Per ct. 1.25 | Per ct. 1.00 | Per ct. 0.25 | 140 | 75 | None | 3.68 | 3.71 | 1.14 | 6864 |
| Lebanon: | 15 | 9 | Smoky | Per ct. 95.23 | Per ct. 7.71 | Per ct. 0.24 | Per ct. 0.87 | Per ct. 0.60 | Per ct. 0.27 | 75 | 74 | do. | 2.28 | 2.75 | 0.87 | 8343 |
| 8344 | | | Fair | Per ct. 96.00 | Per ct. 0.98 | Per ct. 0.24 | Per ct. 0.78 | Per ct. 0.52 | Per ct. 0.21 | 57 | 54 | do. | 1.85 | 2.20 | 0.59 | 8344 |
| Somerset: | 12 | 13 | do. | Per ct. 95.71 | Per ct. 1.54 | Per ct. 1.72 | Per ct. 1.03 | Per ct. 0.71 | Per ct. 0.32 | 89 | 82 | Slight | 3.74 | 4.48 | 1.06 | 6865 |
| | 15 | 13 | do. | Per ct. 95.67 | Per ct. 2.18 | Per ct. 1.20 | Per ct. 0.95 | Per ct. 0.67 | Per ct. 0.28 | 74 | 77 | do. | 3.00 | 3.68 | 0.95 | 6866 |
| | 20 | 11 | Good | Per ct. 97.04 | Per ct. 1.45 | Per ct. 1.10 | Per ct. 0.74 | Per ct. 0.36 | Per ct. 0.06 | 62 | 127 | do. | 3.48 | 3.64 | 1.16 | 6867 |
| | 19 | 13 | do. | Per ct. 94.20 | Per ct. 4.38 | Per ct. 0.37 | Per ct. 1.05 | Per ct. 0.66 | Per ct. 0.39 | 80 | 145 | Trace | 3.05 | 3.89 | 0.97 | 6868 |
| | 11 | 16 | Fair | Per ct. 94.68 | Per ct. 4.40 | Per ct. 1.12 | Per ct. 0.76 | Per ct. 0.36 | Per ct. 0.21 | 81 | 89 | do. | 3.96 | 4.35 | 1.09 | 6869 |
| | 13 | 16 | do. | Per ct. 94.84 | Per ct. 3.76 | Per ct. 0.17 | Per ct. 1.23 | Per ct. 0.87 | Per ct. 0.36 | 106 | 94 | do. | 4.49 | 4.92 | 1.23 | 6870 |
| | 13 | 20+ | Poor | Per ct. 91.09 | Per ct. 6.76 | Per ct. 0.89 | Per ct. 1.26 | Per ct. 0.66 | Per ct. 0.60 | 60 | 138 | do. | 3.69 | 3.74 | 1.07 | 6872 |
| | 8 | 17 | do. | Per ct. 91.21 | Per ct. 7.09 | Per ct. 0.04 | Per ct. 1.11 | Per ct. 0.65 | Per ct. 0.46 | 77 | 96 | do. | 3.88 | 4.39 | 1.14 | 6878 |
| | 17 | 17 | do. | Per ct. 93.12 | Per ct. 5.70 | Per ct. 0.82 | Per ct. 1.14 | Per ct. 0.72 | Per ct. 0.42 | 74 | 117 | do. | 3.70 | 3.87 | 1.01 | 6879 |
| | 13 | 13+ | Fair | Per ct. 93.07 | Per ct. 4.91 | Per ct. 1.06 | Per ct. 1.20 | Per ct. 0.68 | Per ct. 0.52 | 78 | 113 | do. | 4.24 | 4.76 | 1.31 | 6880 |
| | 10 | 16 | Burned | Per ct. 87.10 | Per ct. 10.70 | Per ct. 1.14 | Per ct. 1.14 | Per ct. 0.67 | Per ct. 0.47 | 70 | 95 | do. | 3.82 | 4.55 | 1.15 | 6881 |
| | 6882 | 15 | Fair | Per ct. 95.24 | Per ct. 2.49 | Per ct. 0.88 | Per ct. 1.09 | Per ct. 0.73 | Per ct. 0.36 | 72 | 129 | do. | 3.22 | 3.30 | 0.90 | 6882 |
| | 7515 | 17 | do. | Per ct. 96.80 | Per ct. 1.35 | Per ct. 1.18 | Per ct. 0.97 | Per ct. 0.68 | Per ct. 0.29 | 73 | 64 | do. | 2.38 | 2.73 | 0.93 | 7515 |
| | 7517 | 15 | Good | Per ct. 97.10 | Per ct. 0.54 | Per ct. 1.25 | Per ct. 1.11 | Per ct. 0.68 | Per ct. 0.43 | 83 | 88 | do. | 2.85 | 2.98 | 1.00 | 7517 |
| | Warren: | 14 | 8 | Fair | Per ct. 96.81 | Per ct. 1.77 | Per ct. 0.59 | Per ct. 0.83 | Per ct. 0.64 | Per ct. 0.29 | 64 | 75 | do. | 2.16 | 2.45 | 0.81 | 6430 |
| 13 | | 8 | do. | Per ct. 92.90 | Per ct. 6.32 | Per ct. 0.07 | Per ct. 0.85 | Per ct. 0.53 | Per ct. 0.32 | 70 | 79 | do. | 2.44 | 2.79 | 0.88 | 6431 |
| 11 | | 9 | Poor | Per ct. 57.37 | Per ct. 37.30 | Per ct. 4.15 | Per ct. 1.18 | Per ct. 0.35 | Per ct. 0.37 | 99 | 89 | do. | 3.75 | 4.29 | 1.15 | 6432 |
| 13 | | 9 | Fair | Per ct. 87.90 | Per ct. 10.50 | Per ct. 0.81 | Per ct. 0.79 | Per ct. 0.47 | Per ct. 0.32 | 58 | 73 | do. | 2.16 | 2.75 | 0.85 | 6433 |
| 12 | | 9 | do. | Per ct. 85.03 | Per ct. 13.84 | Per ct. 0.34 | Per ct. 0.79 | Per ct. 0.44 | Per ct. 0.35 | 45 | 81 | do. | 2.10 | 2.73 | 0.77 | 6434 |
| 6435 | | 13 | do. | Per ct. 84.71 | Per ct. 14.50 | Per ct. 0.02 | Per ct. 0.81 | Per ct. 0.54 | Per ct. 0.30 | 66 | 75 | do. | 2.24 | 2.52 | 0.78 | 6435 |

| | | | | | | | | | | | | | | | | | |
|--------------|-----|-----|-------|-------|-------|------|------|------|-----|------|-----|-----|------|--------|------|------|------|
| 6436 | 12 | 11 | do | 87.74 | 10.38 | .82 | .96 | .70 | .26 | 2.69 | 72 | 79 | .91 | do | 2.65 | 3.25 | 6436 |
| 6437 | 11 | 12 | Poor | 96.76 | 2.12 | .28 | .81 | .56 | .25 | 2.24 | 59 | 65 | .90 | Slight | 2.19 | 2.69 | 6437 |
| 6438 | 14 | 10 | Fair | 95.49 | 2.91 | .66 | .94 | .70 | .24 | 2.91 | 70 | 71 | .98 | None | 2.22 | 3.64 | 6438 |
| Wayne D: | | | | | | | | | | | | | | | | | |
| 8329 | (1) | 10 | Good | 93.83 | 3.68 | 1.71 | .78 | .50 | .28 | 1.78 | 68 | 69 | .98 | do | 2.19 | 2.83 | 8329 |
| 8330 | (1) | 9 | do | 95.70 | 1.03 | 2.46 | .81 | .59 | .22 | 2.68 | 83 | 48 | 1.75 | do | 2.01 | 2.49 | 8330 |
| 8331 | (1) | 7 | do | 96.06 | .93 | 1.46 | .81 | .57 | .24 | 2.33 | 77 | 63 | 1.22 | do | 2.26 | 2.71 | 8331 |
| 8332 | 19 | 7+ | Smoky | 96.66 | .88 | 1.62 | .84 | .61 | .23 | 2.65 | 84 | 63 | 1.33 | do | 2.36 | 2.78 | 8332 |
| 8333 | (1) | 7 | do | 96.64 | .45 | 2.01 | .90 | .67 | .23 | 2.91 | 73 | 49 | 1.48 | do | 2.00 | 2.41 | 8333 |
| 8334 | (1) | 9 | Poor | 95.10 | .84 | 2.12 | .94 | .54 | .20 | 1.35 | 70 | 87 | .82 | do | 2.84 | 3.26 | 8334 |
| 8335 | (1) | 7+ | do | 97.43 | 1.20 | 2.30 | 1.07 | .61 | .46 | 1.32 | 80 | 108 | 1.44 | do | 3.13 | 4.07 | 8335 |
| 8336 | (1) | 8 | Good | 97.30 | .53 | 1.37 | .80 | .61 | .23 | 2.48 | 72 | 50 | 1.74 | do | 1.87 | 2.49 | 8336 |
| 8337 | (1) | 9+ | Fair | 93.98 | 3.08 | 2.16 | .78 | .47 | .31 | 1.51 | 62 | 77 | 1.49 | do | 2.50 | 3.02 | 8337 |
| 8338 | 16 | 10 | do | 94.70 | 1.91 | 2.70 | .79 | .56 | .23 | 2.43 | 76 | 51 | 1.49 | do | 1.86 | 2.59 | 8338 |
| 8342 | (1) | 10+ | do | 93.92 | 2.99 | 2.27 | .87 | .58 | .24 | 2.41 | 71 | 63 | 1.12 | do | 2.40 | 2.95 | 8342 |
| 8339 | | | | | | | | | | | | | | | | | 8339 |
| Average (43) | 14 | 11 | do | 92.92 | 4.92 | 1.19 | .97 | .64 | .33 | 1.94 | 74 | 85 | .87 | do | 2.84 | 3.34 | |
| Maximum | 20 | 20+ | do | 97.30 | 37.30 | 4.15 | 1.26 | 1.00 | .60 | 4.00 | 140 | 145 | 1.86 | do | 4.49 | 4.92 | |
| Minimum | 8 | 7 | do | 57.37 | .45 | .02 | .78 | .44 | .21 | 1.10 | 45 | 48 | .43 | do | 1.85 | 2.20 | |

VERMONT.

| | | | | | | | | | | | | | | | | | |
|---------------|----|-----|--------|-------|-------|------|------|------|------|------|----|-----|------|--------|------|------|------|
| Addison D: | 12 | 8+ | Fair | 76.78 | 19.61 | 2.79 | 0.82 | 0.53 | 0.29 | 1.83 | 68 | 65 | 1.05 | None | 1.93 | 3.22 | 6703 |
| 6703 | 11 | 10+ | do | 82.19 | 13.35 | 3.57 | .89 | .50 | .39 | 1.28 | 65 | 90 | .72 | do | 2.55 | 3.83 | 6704 |
| Bennington D: | 9 | 13 | Good | 94.54 | 4.03 | .65 | .78 | .44 | .34 | 1.29 | 60 | 38 | 1.59 | Trace | 1.88 | 2.35 | 6617 |
| Chittenden D: | 12 | 10+ | do | 89.95 | 6.13 | 3.08 | .84 | .60 | .24 | 2.50 | 73 | 59 | 1.23 | do | 2.04 | 3.20 | 6710 |
| 6710 | 8 | 20 | Strong | 89.55 | 5.32 | 3.91 | 1.22 | .67 | .55 | 1.22 | 59 | 113 | .52 | Strong | 2.92 | 3.72 | 6711 |
| 6711 | 10 | 12 | Fair | 81.60 | 14.06 | 3.56 | .78 | .49 | .29 | 1.69 | 93 | 93 | 1.00 | Slight | 2.27 | 3.17 | 6712 |
| Franklin D: | 12 | 13 | do | 89.67 | 8.10 | 1.41 | .82 | .58 | .24 | 2.42 | 64 | 66 | .97 | Trace | 2.28 | 3.13 | 6743 |
| 6743 | 15 | 15 | do | 92.52 | 4.39 | 2.21 | .88 | .54 | .34 | 1.58 | 65 | 93 | .70 | do | 3.05 | 3.27 | 6744 |
| 6744 | 15 | 8 | do | 86.79 | 10.34 | 2.04 | .83 | .53 | .30 | 1.77 | 67 | 51 | .82 | None | 2.46 | 3.74 | 6745 |
| 6745 | 12 | 11 | do | 85.00 | 11.23 | 2.93 | .84 | .58 | .26 | 2.23 | 71 | 72 | .98 | Slight | 2.62 | 3.09 | 6746 |
| 6746 | 12 | 11 | Poor | 90.70 | 5.18 | 3.18 | .94 | .63 | .31 | 2.03 | 77 | 80 | .96 | do | 2.30 | 3.05 | 6747 |
| 6747 | | | | | | | | | | | | | | | | | |
| Lamolle D: | 10 | 13 | Fair | 90.88 | 6.15 | 2.10 | .87 | .45 | .42 | 1.07 | 69 | 97 | .71 | do | 2.54 | 3.28 | 6748 |
| 6748 | 11 | 11 | Good | 92.69 | 4.90 | 1.63 | .78 | .38 | .40 | .95 | 61 | 86 | .71 | None | 2.14 | 2.94 | 6749 |
| 6749 | 13 | 10 | do | 90.52 | 7.08 | 1.56 | .84 | .55 | .29 | 1.90 | 70 | 79 | .89 | do | 2.45 | 3.41 | 6750 |
| 6750 | 12 | 10 | do | 91.40 | 6.29 | 1.53 | .78 | .47 | .31 | 1.52 | 61 | 76 | .80 | do | 2.05 | 2.97 | 6751 |
| 6751 | 12 | 12 | Poor | 89.18 | 7.67 | 2.14 | 1.01 | .47 | .54 | .87 | 65 | 125 | .52 | do | 3.37 | 4.16 | 6752 |
| 6752 | 14 | 10 | Fair | 85.54 | 11.35 | 2.19 | .92 | .40 | .52 | 1.77 | 58 | 113 | .51 | do | 3.06 | 3.78 | 6753 |
| 6753 | 13 | 10 | Good | 91.38 | 6.18 | 2.61 | .83 | .51 | .32 | 1.59 | 68 | 80 | .85 | do | 2.51 | 3.37 | 6754 |
| 6754 | 13 | 10 | Fair | 95.38 | 2.71 | 1.13 | .78 | .51 | .27 | 1.89 | 70 | 67 | 1.04 | do | 2.03 | 2.79 | 6755 |
| 6755 | 12 | 9 | do | 91.36 | 5.49 | 2.32 | .83 | .51 | .32 | 1.59 | 71 | 77 | .92 | do | 2.38 | 3.24 | 6756 |
| 6756 | 12 | 10 | do | 75.39 | 18.53 | 5.12 | .96 | .58 | .38 | 1.52 | 80 | 83 | .96 | do | 3.49 | 3.84 | 6757 |

Average of 34 determinations.

1 Undetermined.

TABLE X.—Results of physical and chemical examination of maple-sugar samples—Continued.
VERMONT—Continued.

| Serial number and county or district. | Physical properties. | | | Chemical analysis. | | | | | | | | | | Lead number. | | Malleic acid value. | Serial number. | |
|---------------------------------------|----------------------|--------|--------|--------------------|---------------|---------------|--------------|--------------|----------------|--------------|--------------|----------------|------------------|--------------|------|---------------------|----------------|------|
| | Color. | | Taste. | Sucrose (Clerget). | Invert sugar. | Undetermined. | Total ash. | Soluble ash. | Insoluble ash. | Soluble ash. | Alkalinity. | | Tannin reaction. | Whitton. | | | | |
| | Sugar. | Sirup. | | | | | | | | | Soluble ash. | Insoluble ash. | | | | | | |
| Lamoille—Continued. | 11 | 11 | Fair | Per ct. 88.06 | Per ct. 9.33 | Per ct. 1.83 | Per ct. 0.78 | Per ct. 0.47 | Per ct. 0.31 | 1.52 | Cc. 58 | Cc. 78 | 0.74 | Slight | 2.63 | 3.11 | 0.81 | 6761 |
| | 10 | 16 | Poor | 88.84 | 9.46 | 1.86 | 0.84 | 0.47 | 0.37 | 1.27 | 55 | 93 | 0.39 | do | 2.38 | 3.82 | 0.90 | 6762 |
| | 13 | 10 | Fair | 87.67 | 9.57 | 1.88 | 0.98 | 0.64 | 0.34 | 1.88 | 77 | 84 | 0.91 | do | 3.40 | 3.80 | 1.00 | 6763 |
| | 14 | 8 | do | 86.50 | 7.15 | 5.51 | 0.84 | 0.52 | 0.32 | 1.62 | 67 | 76 | 0.88 | None | 2.87 | 3.34 | 0.87 | 6764 |
| | 16 | 10 | do | 87.71 | 6.66 | 5.83 | 0.83 | 0.37 | 0.43 | 1.02 | 37 | 96 | 0.88 | do | 2.21 | 2.59 | 0.78 | 6765 |
| | 12 | 10 | do | 90.62 | 7.67 | 7.73 | 0.98 | 0.64 | 0.34 | 1.88 | 78 | 87 | 0.89 | do | 3.45 | 3.90 | 1.02 | 6767 |
| | 15 | 8 | Good | 96.02 | 1.77 | 1.39 | 0.82 | 0.58 | 0.24 | 2.42 | 62 | 58 | 1.07 | do | 2.20 | 2.67 | 0.65 | 7013 |
| | 14 | 11 | do | 90.65 | 5.42 | 3.06 | 0.87 | 0.58 | 0.29 | 2.00 | 71 | 65 | 1.09 | do | 2.20 | 2.79 | 0.74 | 7014 |
| | 13 | 11 | do | 96.48 | 1.99 | 1.60 | 0.93 | 0.69 | 0.24 | 2.88 | 80 | 59 | 1.35 | do | 2.01 | 2.58 | 0.67 | 7015 |
| Orange □: | | | | | | | | | | | | | | | | | | |
| | 14 | | Fair | 94.28 | 79 | 4.03 | 0.90 | 0.43 | 0.47 | 0.91 | 59 | 112 | 0.52 | Slight | 1.90 | 2.51 | 0.73 | 8462 |
| | (1) | 11 | Poor | 92.60 | 2.76 | 3.61 | 1.03 | 0.39 | 0.64 | 0.61 | 62 | 144 | 0.43 | None | 3.13 | 3.83 | 1.21 | 8465 |
| Orleans □: | | | | | | | | | | | | | | | | | | |
| | 11 | 11 | Fair | 83.14 | 13.72 | 2.19 | 0.95 | 0.65 | 0.30 | 2.17 | 79 | 79 | 1.00 | do | 3.34 | 3.91 | 0.95 | 6783 |
| | 13 | 10+ | do | 83.36 | 13.54 | 2.10 | 1.00 | 0.44 | 0.56 | 2.78 | 46 | 123 | 0.37 | Slight | 2.90 | 3.78 | 1.05 | 6784 |
| | 10 | 12 | do | 75.97 | 19.01 | 3.79 | 1.23 | 0.56 | 0.67 | 0.83 | 71 | 106 | 0.67 | do | 3.82 | 4.60 | 1.30 | 6785 |
| | 12 | 16 | Strong | 89.15 | 8.02 | 1.60 | 1.23 | 0.64 | 0.59 | 1.08 | 78 | 124 | 0.63 | do | 3.78 | 4.53 | 1.17 | 6786 |
| | 11 | 9 | Fair | 73.58 | 22.62 | 2.84 | 0.96 | 0.56 | 0.40 | 1.40 | 68 | 97 | 0.70 | do | 3.22 | 4.07 | 1.09 | 6787 |
| | 11 | 13 | Burned | 85.26 | 11.02 | 2.62 | 1.10 | 0.49 | 0.61 | 1.80 | 58 | 132 | 0.44 | do | 3.58 | 3.58 | 1.18 | 6788 |
| | 15 | 11 | Fair | 83.05 | 12.71 | 3.18 | 1.06 | 0.43 | 0.63 | 0.68 | 56 | 131 | 0.43 | do | 3.38 | 4.10 | 1.17 | 6789 |
| | 11 | 9 | Poor | 71.85 | 23.22 | 3.05 | 1.88 | 0.53 | 0.35 | 1.51 | 65 | 131 | 0.78 | None | 2.85 | 3.71 | 0.94 | 6791 |
| | 10 | 11 | do | 70.40 | 25.00 | 3.64 | 0.96 | 0.53 | 0.50 | 1.04 | 62 | 119 | 0.55 | Slight | 3.60 | 4.38 | 1.21 | 6792 |
| | 12 | 11 | Fair | 85.56 | 11.07 | 2.35 | 1.02 | 0.52 | 0.43 | 1.23 | 62 | 112 | 0.52 | None | 3.69 | 4.28 | 1.19 | 6793 |
| | 12 | 11 | do | 81.38 | 13.80 | 2.80 | 1.02 | 0.45 | 0.57 | 1.78 | 48 | 121 | 0.40 | Slight | 3.21 | 3.88 | 1.10 | 6794 |
| | 9 | 20+ | do | 85.60 | 11.28 | 1.71 | 1.41 | 0.60 | 0.81 | 0.74 | 66 | 166 | 0.39 | Strong | 3.60 | 4.16 | 1.25 | 6797 |
| | 9 | 9 | Poor | 83.62 | 12.35 | 2.83 | 1.20 | 0.56 | 0.64 | 0.88 | 64 | 109 | 0.58 | Slight | 3.67 | 4.03 | 1.03 | 6798 |
| | 11 | 14 | Fair | 83.56 | 12.88 | 2.50 | 1.06 | 0.55 | 0.51 | 1.08 | 65 | 105 | 0.02 | do | 4.06 | 4.63 | 1.20 | 6799 |
| | 11 | 20 | Burned | 74.53 | 23.85 | 2.84 | 1.12 | 0.64 | 0.48 | 1.34 | 81 | 110 | 0.73 | None | 3.59 | 4.10 | 1.10 | 6800 |
| | 13 | 10 | Good | 97.49 | 1.07 | 0.53 | 0.91 | 0.61 | 0.30 | 2.03 | 83 | 65 | 1.27 | do | 1.98 | 2.49 | 0.67 | 7012 |
| Rutland □: | | | | | | | | | | | | | | | | | | |
| | 14 | 8 | Fair | 95.22 | 3.48 | 0.50 | 0.80 | 0.54 | 0.26 | 2.07 | 62 | 89 | 0.70 | do | 2.25 | 3.20 | 0.91 | 6844 |
| | 13 | 12 | Good | 96.63 | 1.29 | 1.08 | 1.00 | 0.68 | 0.32 | 2.12 | 77 | 79 | 0.98 | do | 2.16 | 2.93 | 0.85 | 6846 |

| | | | | | | | | | | | | | | | | |
|---------------|-----|-------|-------|------|------|-----|-----|------|----|-----|------|-----------|-------|------|------|-------|
| Washington □: | 5 | 96.76 | .09 | 2.33 | .82 | .45 | .37 | 1.22 | 62 | 76 | .82 | ...do.... | 1.98 | 2.57 | .82 | 8384 |
| 8384..... | 14 | 90.06 | 8.28 | .72 | .94 | .66 | .28 | 2.36 | 66 | 75 | .88 | ...do.... | 2.85 | 3.42 | .97 | 6618 |
| Windham □: | 8 | 79.43 | 18.93 | .81 | .83 | .52 | .31 | 1.68 | 68 | 80 | .85 | ...do.... | 2.87 | 3.71 | .95 | 6619 |
| 6619..... | 12 | 83.78 | 12.90 | 2.32 | 1.00 | .70 | .30 | 2.33 | 84 | 88 | .95 | ...do.... | 3.31 | 3.88 | 1.11 | 6620 |
| 6620..... | 10 | | | | | | | | | | | | | | | |
| Windsor □: | 9 | 96.88 | .64 | 1.57 | .91 | .62 | .29 | 2.14 | 73 | 73 | 1.00 | ...do.... | 2.36 | 3.01 | .85 | 8368 |
| 8368..... | 10 | 96.85 | .41 | 1.86 | .88 | .55 | .33 | 1.67 | 72 | 78 | .92 | ...do.... | 2.28 | 3.13 | .88 | 8369 |
| 8369..... | 7+ | 97.56 | .22 | 1.38 | .84 | .56 | .28 | 2.00 | 78 | 66 | 1.18 | ...do.... | 2.25 | 2.98 | .84 | 8371 |
| 8371..... | 9 | 95.65 | 1.05 | 2.52 | .78 | .47 | .31 | 1.52 | 56 | 77 | .72 | ...do.... | 1.94 | 2.62 | .67 | 8377 |
| 8377..... | 8 | 94.17 | .44 | 4.58 | .81 | .52 | .29 | 1.79 | 65 | 74 | .87 | ...do.... | 2.02 | 2.64 | .81 | 8380 |
| 8380..... | (1) | 91.93 | 4.09 | 3.16 | .82 | .49 | .33 | 1.48 | 56 | 90 | .62 | ...do.... | 2.11 | 3.07 | .69 | 8381 |
| 8381..... | (1) | 96.70 | .43 | 1.99 | .88 | .59 | .29 | 2.03 | 65 | 84 | .77 | ...do.... | 2.28 | 3.00 | .51 | 8379 |
| 8379..... | 10 | 93.16 | 2.76 | 3.31 | .77 | .50 | .27 | 1.84 | 50 | 67 | .79 | ...do.... | 2.20 | 2.20 | .66 | 8420 |
| 8420..... | 12 | 93.68 | 2.47 | 3.01 | .84 | .55 | .29 | 1.90 | 70 | 73 | .95 | ...do.... | 1.86 | 2.76 | .67 | 8476 |
| 8476..... | 12+ | | | | | | | | | | | | | | | |
| Average (63) | 212 | 88.39 | 8.37 | 2.52 | .92 | .54 | .38 | 1.42 | 66 | 89 | .74 | ..... | 3.270 | 3.39 | .92 | ..... |
| Maximum | 11 | 97.56 | 25.00 | 5.31 | 1.41 | .70 | .81 | 2.88 | 93 | 132 | 1.59 | ..... | 4.06 | 4.63 | 1.30 | ..... |
| Minimum | 5 | 70.40 | .09 | .50 | .77 | .37 | .24 | .61 | 37 | 38 | .37 | ..... | 1.86 | 2.35 | .51 | ..... |

WEST VIRGINIA.

| | | | | | | | | | | | | | | | | |
|---------------|----|-------|-------|------|------|------|------|------|-----|-----|------|------------|------|------|------|-------|
| Grant □: | 12 | 90.62 | 6.37 | 1.59 | 1.42 | 0.82 | 0.60 | 1.37 | 93 | 142 | 0.65 | Slight.... | 4.09 | 4.42 | 1.53 | 7501 |
| 7501..... | 10 | 95.50 | 2.47 | .62 | 1.41 | .82 | .59 | 1.39 | 71 | 126 | .57 | ...do.... | 4.05 | 4.23 | 1.13 | 7502 |
| 7502..... | 10 | 90.48 | 5.97 | 2.10 | 1.45 | .83 | .62 | 1.34 | 104 | 133 | .78 | ...do.... | 4.64 | 4.70 | 1.56 | 7503 |
| 7503..... | 10 | 94.48 | 3.59 | .84 | 1.09 | .65 | .44 | 1.48 | 88 | 109 | .80 | None.... | 3.44 | 3.74 | 1.25 | 7504 |
| 7504..... | 14 | 97.25 | .98 | .61 | 1.16 | .71 | .45 | 1.48 | 91 | 115 | .79 | ...do.... | 3.04 | 3.44 | 1.15 | 7505 |
| 7505..... | 11 | | | | | | | | | | | | | | | |
| Greenbrier □: | 12 | 84.06 | 13.69 | .88 | 1.37 | .91 | .46 | 1.98 | 102 | 102 | 1.00 | Slight.... | 3.72 | 4.99 | 1.34 | 6687 |
| 6687..... | 11 | 85.65 | 10.82 | 1.87 | 1.66 | 1.14 | .52 | 2.18 | 124 | 130 | .95 | ...do.... | 4.95 | 5.90 | 1.72 | 6688 |
| 6688..... | 13 | | | | | | | | | | | | | | | |
| Average (7) | 12 | 91.15 | 6.27 | 1.21 | 1.37 | .84 | .63 | 1.58 | 96 | 122 | .79 | ..... | 3.99 | 4.49 | 1.38 | ..... |
| Maximum | 16 | 97.25 | 13.69 | 2.10 | 1.66 | 1.14 | .62 | 2.18 | 124 | 142 | 1.00 | ..... | 4.95 | 5.90 | 1.72 | ..... |
| Minimum | 10 | 84.06 | .98 | .61 | 1.09 | .65 | .44 | 1.34 | 71 | 102 | .57 | ..... | 3.04 | 3.44 | 1.13 | ..... |

UNITED STATES.

| | | | | | | | | | | | | | | | | |
|---------------|-----|-------|-------|------|------|------|------|------|-----|-----|------|-------|------|------|------|-------|
| Average (283) | 413 | 91.89 | 5.46 | 1.70 | 0.95 | 0.62 | 0.33 | 1.88 | 74 | 82 | .90 | ..... | 2.68 | 3.34 | 0.91 | ..... |
| Maximum | 21 | 98.62 | 37.30 | 5.84 | 1.66 | 1.14 | .81 | 4.07 | 140 | 149 | 2.29 | ..... | 4.95 | 5.90 | 1.72 | ..... |
| Minimum | 8 | 57.04 | 0.09 | 0.00 | .76 | .37 | .21 | .61 | 37 | 31 | .37 | ..... | 1.85 | 2.20 | .51 | ..... |

¹ Undetermined. ² Average of 54 determinations. ³ Average of 62 determinations. ⁴ Average of 247 determinations. ⁵ Average of 282 determinations.

TABLE X.—Results of physical and chemical examination of maple-sugar samples—Continued.

QUEBEC, CANADA

| Serial number and county or district. | Physical properties. | | Chemical analysis. | | | | | | | | | | Lead number. | | Maleic acid value. | Serial number. | | |
|---------------------------------------|----------------------|--------|--------------------|--------------------|---------------|---------------|--------------|--------------|----------------|--------------|--------------|----------------|------------------|----------|--------------------|----------------|-------|------|
| | Color. | | Taste. | Sucrose (Clerget). | Invert sugar. | Undetermined. | Total ash. | Soluble ash. | Insoluble ash. | Soluble ash. | Alkalinity. | | Tannin reaction. | Win-ton. | | | | |
| | Sugar. | Sirup. | | | | | | | | | Soluble ash. | Insoluble ash. | | | | | ° Cc. | |
| Shefford, Brome, and Stanstead. | 8 | 20+ | Strong. | Per ct. 74.11 | Per ct. 18.20 | Per ct. 6.47 | Per ct. 1.22 | Per ct. 0.60 | Per ct. 0.62 | 0.96 | Cc. 50 | 90 | 0.55 | None. | 4.13 | 4.51 | 1.35 | 6716 |
| | 10 | 20+ | do. | 91.22 | 4.15 | 3.29 | 1.34 | .69 | .65 | 1.06 | 54 | 118 | .46 | Good. | 3.69 | 4.37 | 1.22 | 6717 |
| | 13 | 13+ | Poor. | 90.38 | 6.95 | 1.83 | .84 | .60 | .24 | 2.50 | 75 | 53 | 1.41 | Slight. | 2.36 | 3.08 | .78 | 6938 |
| | 11 | 14 | do. | 67.57 | 27.31 | 4.24 | .88 | .49 | .39 | 1.26 | 65 | 93 | .70 | do. | 2.71 | 3.64 | .96 | 6939 |
| | 13 | 10 | Good. | 92.74 | 4.61 | 1.83 | .82 | .46 | .36 | 1.28 | 65 | 82 | .86 | None. | 2.43 | 3.33 | .87 | 6940 |
| | 11 | 18 | Fair. | 83.38 | 11.71 | 3.88 | 1.09 | .48 | .61 | 1.78 | 66 | 130 | .51 | Slight. | 3.13 | 3.94 | 1.10 | 6941 |
| | 12 | 13 | Good. | 93.87 | 3.99 | 1.10 | 1.04 | .60 | .44 | 1.36 | 68 | 103 | .66 | None. | 3.22 | 3.96 | 1.01 | 6942 |
| | 11 | 18 | Fair. | 93.31 | 4.50 | 1.18 | 1.01 | .45 | .56 | 1.80 | 50 | 124 | .40 | Slight. | 3.69 | 3.77 | 1.02 | 6943 |
| | 12 | 17 | do. | 90.87 | 6.86 | 1.30 | .97 | .51 | .46 | 1.11 | 66 | 99 | .67 | do. | 2.42 | 3.99 | 1.00 | 6944 |
| | 11 | 12+ | do. | 91.56 | 5.86 | 1.15 | .83 | .49 | .34 | 1.14 | 61 | 78 | .81 | do. | 2.35 | 3.42 | .77 | 6945 |
| | 8 | 20 | Strong. | 88.31 | 9.03 | 1.62 | 1.04 | .48 | .56 | .86 | 67 | 119 | .56 | do. | 3.32 | 4.45 | 1.04 | 6946 |
| | 15 | 8 | Good. | 89.22 | 8.93 | 1.04 | .81 | .46 | .35 | 1.31 | 57 | 79 | .72 | None. | 2.48 | 3.56 | .88 | 6947 |
| | 13 | 12 | do. | 91.92 | 5.61 | 1.63 | .84 | .50 | .34 | 1.47 | 67 | 76 | .89 | Slight. | 3.52 | 3.31 | .80 | 6948 |
| | 12 | 13 | Poor. | 94.27 | 2.77 | 2.12 | .84 | .44 | .40 | 1.10 | 63 | 83 | .71 | None. | 2.43 | 3.38 | .92 | 6949 |
| | 13 | 9 | Good. | 90.04 | 9.09 | .02 | .85 | .47 | .38 | 1.24 | 62 | 86 | .72 | do. | 2.46 | 3.60 | .94 | 6950 |
| | 12 | 15 | Fair. | 89.04 | 6.61 | 3.39 | .96 | .64 | .32 | 2.00 | 77 | 78 | .98 | Slight. | 2.68 | 3.56 | .91 | 6951 |
| | 8 | 20+ | Strong. | 86.80 | 8.83 | 3.44 | .93 | .39 | .54 | .72 | 52 | 117 | .44 | do. | 2.46 | 3.83 | .98 | 6952 |
| 6953. | 10 | 20+ | do. | 88.17 | 6.28 | 4.39 | 1.16 | .61 | .55 | 1.11 | 79 | 128 | .61 | do. | 2.87 | 4.24 | 1.15 | 6953 |
| 6954. | (1) | 20+ | Fair. | 90.05 | 8.85 | 3.41 | .91 | .62 | .29 | 2.14 | 69 | 83 | .83 | Strong. | 2.48 | 3.01 | .81 | 6954 |
| 6955. | (1) | 13 | Good. | 96.59 | .88 | 1.67 | .86 | .51 | .35 | 1.46 | 88 | 65 | 1.36 | None. | 2.03 | 2.74 | .77 | 6955 |
| 6956. | (1) | 13 | Fair. | 93.51 | 2.15 | 3.37 | .97 | .71 | .26 | 2.73 | 80 | 81 | .98 | do. | 2.90 | 3.39 | 1.03 | 6956 |
| 6957. | (1) | 13 | do. | 74.66 | 19.13 | 5.28 | .93 | .64 | .29 | 2.21 | 71 | 82 | .86 | Slight. | 2.99 | 4.01 | 1.04 | 6957 |
| 7596. | 17 | 7 | Good. | 92.97 | 5.42 | .83 | .78 | .51 | .27 | 1.89 | 64 | 73 | .87 | None. | 2.16 | 2.82 | .79 | 7596 |
| 7599. | 8- | 20+ | Strong. | 81.26 | 13.98 | 3.35 | 1.41 | .68 | .73 | .93 | 84 | 144 | .58 | Strong. | 3.12 | 3.63 | .96 | 7599 |
| Average (24). | 21+ | 15 | do. | 88.16 | 8.23 | 2.64 | .97 | .51 | .43 | 1.25 | 66 | 94 | .70 | do. | 2.83 | 3.66 | .96 | |
| Maximum. | 17 | 20+ | do. | 96.59 | 27.31 | 6.47 | 1.41 | .71 | .73 | 2.73 | 88 | 144 | 1.41 | do. | 4.13 | 4.51 | 1.35 | |
| Minimum. | 8 | 7 | do. | 67.57 | .88 | .02 | .78 | .39 | .24 | .72 | 50 | 53 | .40 | do. | 2.03 | 2.74 | .77 | |

| Johette: | 9 | 12 | Good | 87.73 | 8.51 | 2.83 | .93 | .03 | .30 | 2.10 | 75 | 85 | Trace | .89 | (1) | 2.86 | .90 |
|------------------------------------|----|-----|--------|-------|-------|------|------|-----|-----|------|------|-----|-------|------|-----|------|------|
| | | | | | | | | | | | | | | | | | |
| 7710 | 10 | 14 | do. | 94.38 | 4.72 | 2.03 | .87 | .63 | .24 | 2.62 | 70 | 58 | do. | 1.21 | (1) | 2.11 | 7710 |
| 7715 | 9 | 13 | do. | 93.95 | 5.73 | 2.36 | .96 | .64 | .32 | 2.00 | 83 | 86 | do. | .96 | (1) | 2.72 | 7715 |
| 7717 | 13 | 10 | do. | 90.90 | 5.88 | 2.94 | .78 | .53 | .25 | 2.12 | 78 | 86 | do. | 1.18 | (1) | 2.34 | 7717 |
| 7718 | 10 | 10+ | do. | 88.36 | 7.64 | 3.14 | .85 | .59 | .26 | 2.37 | 80 | 72 | do. | 1.11 | (1) | 2.51 | 7718 |
| 7719 | 11 | 14+ | do. | 92.71 | 4.62 | 2.22 | 1.05 | .80 | .25 | 2.30 | 116 | 75 | do. | 1.54 | (1) | 3.10 | 7719 |
| 7720 | 9 | 18 | Fair | 83.45 | 12.00 | 3.42 | 1.15 | .80 | .35 | 2.38 | 101 | 101 | do. | 1.14 | (1) | 3.49 | 7720 |
| 7721 | 8 | 20+ | Bad | 83.23 | 10.76 | 4.89 | 1.10 | .70 | .40 | 1.75 | 87 | 113 | Trace | 1.77 | (1) | 3.69 | 7721 |
| 7729 | 8 | 20+ | Good | 83.25 | 4.61 | 2.96 | 1.10 | .84 | .24 | 2.95 | 71 | 68 | do. | 1.04 | (1) | 3.56 | 7729 |
| 7730 | 8 | 18 | do. | 84.67 | 8.90 | 5.20 | .78 | .53 | .40 | 2.07 | 120 | 120 | do. | 1.00 | (1) | 2.37 | 7730 |
| 7738 | 8 | 20+ | Bad | 80.99 | 11.70 | 5.97 | 1.23 | .82 | .62 | 1.15 | 93 | 141 | do. | .66 | (1) | 3.70 | 7738 |
| 7739 | 8 | 20+ | do. | 80.99 | 11.70 | 5.97 | 1.23 | .82 | .62 | 1.15 | 93 | 141 | do. | .66 | (1) | 3.49 | 7739 |
| 7742 | 8 | 20+ | Burned | 70.35 | 21.70 | 6.54 | 1.41 | .68 | .37 | 1.83 | 86 | 152 | do. | .57 | (1) | 3.32 | 7742 |
| Average (12) | | | | | | | | | | | | | | | | | |
| Maximum | | | | 86.79 | 8.55 | 3.62 | 1.04 | .67 | .37 | 1.81 | 90 | 95 | | | | 2.99 | 1.02 |
| Minimum | | | | 94.38 | 21.70 | 6.54 | 1.41 | .83 | .73 | 3.30 | 1.20 | 152 | | | | 3.70 | 1.34 |
| | | | | 70.35 | 2.73 | .03 | .78 | .53 | .24 | .83 | 70 | 58 | | | | 2.11 | .62 |
| Arthabaska, Megan-
tic, Beauce: | 9 | 12+ | Good | 94.11 | 2.27 | 2.62 | 1.00 | .61 | .39 | 1.57 | 75 | 95 | None | .80 | (1) | 2.50 | .88 |
| | | | | | | | | | | | | | | | | | |
| 7708 | 8 | 12 | do. | 90.85 | 5.24 | 2.85 | 1.06 | .50 | .46 | 1.09 | 62 | 83 | do. | .70 | (1) | 2.61 | 7708 |
| 7709 | 11 | 12 | Fair | 91.00 | 3.04 | 2.52 | .97 | .43 | .30 | 1.00 | 65 | 62 | do. | 1.05 | (1) | 2.55 | 7709 |
| 7711 | 13 | 11+ | do. | 89.27 | 5.45 | 2.74 | 1.13 | .67 | .29 | 2.23 | 85 | 79 | do. | 1.08 | (1) | 2.96 | 7711 |
| 7712 | 10 | 15 | do. | 89.67 | 5.45 | 2.74 | 1.13 | .63 | .29 | 2.23 | 85 | 79 | do. | 1.08 | (1) | 2.96 | 7712 |
| 7713 | 13 | 12+ | do. | 93.51 | 3.95 | 2.85 | 1.08 | .63 | .27 | 2.33 | 81 | 112 | do. | 1.72 | (1) | 3.30 | 7713 |
| 7714 | 10 | 16 | Good | 92.22 | 3.95 | 2.85 | 1.08 | .63 | .27 | 2.33 | 81 | 112 | do. | 1.72 | (1) | 3.30 | 7714 |
| 7716 | 10 | 16 | do. | 92.22 | 3.95 | 2.85 | 1.08 | .63 | .27 | 2.33 | 81 | 112 | do. | 1.72 | (1) | 3.30 | 7716 |
| 7722 | 8 | 20+ | Fair | 79.88 | 12.83 | 4.91 | 1.16 | .59 | .49 | 1.21 | 83 | 103 | do. | .93 | (1) | 3.24 | 7722 |
| 7723 | 8 | 20+ | Good | 81.83 | 12.83 | 4.91 | 1.16 | .59 | .49 | 1.21 | 83 | 103 | do. | .93 | (1) | 3.24 | 7723 |
| 7724 | 8 | 20 | do. | 88.39 | 4.91 | 4.32 | 1.18 | .79 | .39 | 2.02 | 116 | 138 | Trace | .70 | (1) | 3.59 | 7724 |
| 7725 | 8 | 20 | Fair | 88.39 | 4.91 | 4.32 | 1.18 | .79 | .39 | 2.02 | 116 | 138 | do. | .70 | (1) | 3.59 | 7725 |
| 7726 | 10 | 16 | do. | 89.32 | 4.55 | 5.08 | 1.05 | .68 | .41 | 1.65 | 104 | 111 | do. | 1.96 | (1) | 3.79 | 7726 |
| 7727 | 9 | 20 | Good | 89.32 | 4.55 | 5.08 | 1.05 | .68 | .41 | 1.65 | 104 | 111 | do. | 1.96 | (1) | 3.79 | 7727 |
| 7728 | 10 | 16 | do. | 90.37 | 5.60 | 4.07 | 1.11 | .71 | .40 | 1.78 | 90 | 106 | do. | .85 | (1) | 3.10 | 7728 |
| 7729 | 11 | 14 | do. | 91.99 | 3.59 | 3.47 | .89 | .65 | .26 | 2.65 | 87 | 72 | do. | 1.20 | (1) | 3.02 | 7729 |
| 7732 | 11 | 14 | do. | 91.14 | 3.50 | 2.07 | .89 | .65 | .24 | 2.70 | 82 | 71 | do. | 1.15 | (1) | 2.41 | 7732 |
| 7733 | 8 | 20+ | Bad | 84.44 | 10.50 | 3.86 | 1.20 | .76 | .44 | 1.73 | 93 | 115 | do. | .80 | (1) | 2.64 | 7733 |
| 7734 | 8 | 20+ | Fair | 89.46 | 4.63 | 4.10 | 1.13 | .73 | .44 | 1.82 | 90 | 113 | Trace | .80 | (1) | 3.24 | 7734 |
| 7735 | 8 | 20+ | do. | 88.29 | 6.64 | 4.78 | 1.33 | .73 | .44 | 1.82 | 90 | 113 | do. | .80 | (1) | 3.19 | 7735 |
| 7736 | 8 | 20+ | do. | 88.29 | 6.64 | 4.78 | 1.33 | .73 | .44 | 1.82 | 90 | 113 | do. | .80 | (1) | 3.40 | 7736 |
| 7737 | 8 | 20+ | do. | 88.29 | 6.64 | 4.78 | 1.33 | .73 | .44 | 1.82 | 90 | 113 | do. | .80 | (1) | 3.20 | 7737 |
| 7738 | 8 | 20+ | do. | 88.29 | 6.64 | 4.78 | 1.33 | .73 | .44 | 1.82 | 90 | 113 | do. | .80 | (1) | 2.80 | 7738 |
| 7739 | 10 | 13 | Good | 90.09 | 5.27 | 3.80 | .84 | .55 | .29 | 1.90 | 72 | 82 | do. | 1.78 | (1) | 2.49 | 7739 |
| 7740 | 9 | 20+ | do. | 88.26 | 7.10 | 3.73 | .91 | .58 | .33 | 1.76 | 75 | 88 | do. | .88 | (1) | 2.80 | 7740 |
| 7741 | 8 | 20+ | Burned | 85.26 | 85.26 | 5.06 | 1.25 | .70 | .48 | 1.69 | 42 | 103 | Trace | .88 | (1) | 2.72 | 7741 |
| 7743 | 8 | 20+ | do. | 85.92 | 85.26 | 5.06 | 1.25 | .70 | .48 | 1.69 | 42 | 103 | do. | .88 | (1) | 1.86 | 7743 |
| 7744 | 8 | 20+ | Good | 85.23 | 8.52 | 5.00 | 1.25 | .70 | .48 | 1.69 | 42 | 103 | do. | .88 | (1) | 1.75 | 7744 |
| 7745 | 8 | 20+ | Burned | 81.20 | 10.82 | 6.20 | 1.20 | .70 | .44 | 1.75 | 93 | 126 | do. | .73 | (1) | 3.24 | 7745 |
| 7746 | 8 | 20+ | do. | 83.54 | 11.02 | 4.23 | 1.21 | .77 | .44 | 1.75 | 93 | 126 | do. | .73 | (1) | 3.47 | 7746 |
| 7747 | 8 | 20+ | do. | 83.54 | 11.02 | 4.23 | 1.21 | .77 | .44 | 1.75 | 93 | 126 | do. | .73 | (1) | 2.98 | 7747 |
| 7748 | 8 | 20+ | do. | 83.54 | 11.02 | 4.23 | 1.21 | .77 | .44 | 1.75 | 93 | 126 | do. | .73 | (1) | 3.00 | 7748 |
| 7749 | 8 | 20+ | do. | 83.54 | 11.02 | 4.23 | 1.21 | .77 | .44 | 1.75 | 93 | 126 | do. | .73 | (1) | 3.14 | 7749 |
| 7750 | 8 | 20+ | do. | 83.54 | 11.02 | 4.23 | 1.21 | .77 | .44 | 1.75 | 93 | 126 | do. | .73 | (1) | 3.34 | 7750 |
| 7750 | 8 | 20+ | do. | 77.16 | 13.42 | 8.18 | 1.24 | .56 | .68 | 1.01 | 107 | 141 | do. | .75 | (1) | 3.84 | 7750 |

³ Average of 25 determinations.

² Average of 20 determinations.

¹ Undetermined.

TABLE X.—*Results of physical and chemical examination of maple-sugar samples—Continued.*
QUEBEC, CANADA—Continued.

| Serial number and county or district. | Physical properties. | | Chemical analysis. | | | | | | | | | | Lead number. | | Malic acid value. | Serial number. | |
|---------------------------------------|----------------------|--------|--------------------|--------------------|---------------|---------------|--------------|--------------|----------------|--------------|---------------|-----------------|------------------|----------|-------------------|----------------|-------|
| | Color. | | Taste. | Sucrose (Clerget). | Invert sugar. | Undetermined. | Total ash. | Soluble ash. | Insoluble ash. | Soluble ash. | Alkalinity. | | Tannin reaction. | Win-ton. | | | Loss. |
| | Sugar. | Sirup. | | | | | | | | | Solu-ble ash. | Insolu-ble ash. | | | | | |
| Arthabaska, Mégantic, Beauce—Cont'd. | 10 | 13 | Fair | Per ct. 93.67 | Per ct. 3.56 | Per ct. 1.86 | Per ct. 0.91 | Per ct. 0.66 | Per ct. 0.25 | 2.64 | 1.04 | None | 4.02 | 3.53 | 0.94 | 7500 | |
| | 13 | 19 | Poor | 80.24 | 14.43 | 4.16 | 1.17 | .77 | .40 | 1.62 | .89 | Trace | 3.46 | (1) | 1.11 | 7520 | |
| | 8 | 20+ | do. | 86.00 | 7.26 | 5.61 | 1.13 | .69 | .44 | 1.56 | .82 | Trace | 3.80 | (1) | .99 | 7522 | |
| | 10 | 20 | do. | 91.54 | 2.06 | 4.99 | 1.41 | .80 | .61 | 1.31 | .78 | Trace | 3.27 | (1) | 1.15 | 7523 | |
| | 8 | 20 | do. | 7597 | 83.75 | 14.04 | 5.97 | 1.24 | .72 | .52 | 1.38 | .60 | Slight | 3.31 | 4.07 | .89 | 7597 |
| | 8 | 20+ | do. | 82.65 | 10.46 | 5.52 | 1.37 | .58 | .79 | 1.73 | .65 | do. | 3.34 | (1) | 1.15 | 7449 | |
| | 11 | 13 | do. | 88.94 | 4.75 | 5.45 | .86 | .47 | .39 | 1.20 | .57 | None | 2.30 | (1) | .85 | 7478 | |
| | 12 | 18 | do. | 89.50 | 5.44 | 4.09 | .97 | .55 | .42 | 1.31 | .69 | Trace | 2.91 | (1) | .91 | 7479 | |
| | 10 | 20+ | do. | 81.61 | 12.37 | 4.79 | 1.23 | .89 | .34 | 2.61 | .91 | Trace | 3.47 | (1) | 1.02 | 7484 | |
| | 8 | 20+ | do. | 76.96 | 16.20 | 5.73 | 1.11 | .62 | .49 | 1.27 | .67 | Slight | 3.82 | (1) | 1.06 | 7651 | |
| | 8 | 20+ | do. | 86.34 | 7.13 | 4.35 | 1.13 | .66 | .52 | 1.26 | .79 | do. | 3.62 | (1) | 1.13 | 7658 | |
| | 12 | 20+ | do. | 75.05 | 17.29 | 6.11 | 1.55 | .67 | .88 | .76 | .76 | do. | 4.14 | (1) | 1.51 | 7659 | |
| | 8 | 20+ | Good | 85.12 | 9.10 | 4.83 | .95 | .54 | .41 | 1.31 | .85 | Trace | 3.24 | (1) | 1.15 | 7814 | |
| Average (44) | 9 | 17+ | | 85.46 | 9.11 | 4.31 | 1.12 | .63 | .49 | 1.28 | .83 | | 3.16 | (1) | 1.07 | | |
| | 13 | 20+ | Maximum | 94.11 | 35.26 | 8.18 | 1.70 | .89 | 1.00 | 2.70 | 1.17 | | 4.14 | (1) | 1.51 | | |
| | 8 | 11 | Minimum | 58.92 | 2.06 | 1.05 | .76 | .31 | .24 | .43 | .62 | | 1.86 | (1) | .65 | | |
| Canada: | 10 | 16+ | | 86.48 | 8.76 | 3.70 | 1.06 | .61 | .45 | 1.36 | .79 | | 3.04 | (1) | 1.03 | | |
| | 17 | 20+ | Maximum | 96.59 | 35.26 | 8.18 | 1.70 | .89 | 1.00 | 3.20 | 1.20 | | 4.14 | (1) | 1.51 | | |
| | 8 | 7 | Minimum | 58.92 | .88 | .02 | .76 | .31 | .24 | .43 | .42 | | 1.86 | (1) | .62 | | |
| United States and Canada: | 12+ | 13+ | | 90.69 | 6.19 | 2.14 | .98 | .62 | .36 | 1.69 | .75 | | 2.76 | 23.50 | .93 | | |
| | 21 | 20+ | Maximum | 98.62 | 35.26 | 8.18 | 1.70 | 1.14 | 1.00 | 4.07 | 1.40 | | 4.95 | 25.90 | 1.72 | | |
| | 8 | 7 | Minimum | 57.04 | .00 | .00 | .76 | .30 | .21 | .43 | .42 | | 1.85 | 2.20 | .51 | | |

1 Undetermined.

2 Average of 308 determinations.

DISCUSSION OF RESULTS.

COLOR.

Sugar.—The color of a maple sugar, although not necessarily an indication of its quality, is influenced by the crystallization and by the dryness of the sugar. Very dark maple sirup, if free from sediment, when boiled down nearly to dryness and stirred gives a very light-colored sugar. If this sugar is powdered, the color and appearance are similar to those of the ordinary powdered cane sugar, although it possesses a maple flavor. Such sugar can also be produced with greater ease from a light-colored sirup. The color of the sugars varies from 8, the darkest, to 21, the lightest, the average of the individual States showing slight variations from 12 to 15. No comparison has been made between the Canadian and the United States samples.

Sirup.—The average color of the United States sugar-sirup samples is 11, which is three points darker than that of the sap sirups. Table XI shows the average color of the sugar sirups as well as that of the sap sirups for the several States.

TABLE XI.—Average color of sugar sirup and sap sirup, by States.

| State. | Sugar sirup | Sap sirup. ¹ | State. | Sugar sirup. | Sap sirup. ¹ |
|--------------------|-------------|-------------------------|--------------------|--------------|-------------------------|
| Indiana..... | 10+ | 10+ | New York..... | 10 | 7 |
| Maine..... | 11 | 8+ | Ohio..... | 10 | 8 |
| Maryland..... | 11 | (²) | Pennsylvania..... | 11 | 8 |
| Massachusetts..... | 9 | 7 | Vermont..... | 11 | 9 |
| Michigan..... | 11 | 8+ | West Virginia..... | 12 | 9 |
| New Hampshire..... | 10 | 8 | United States..... | 11 | 8+ |

¹ U. S. Dept Agr., Bur. Chem. Bul. 134.

² No sample.

In only one State, Indiana, is the color of the sap sirup equal to the sugar sirup, there being in all others a difference of at least two points.

TASTE.

The flavor of a maple product is an indescribable property. It is usually possible for a person with an acute sense of taste to differentiate between sap sirup and sugar sirup after a very few trials.

SUCROSE.

The average percentage of sucrose in the sugars when reduced to the dry basis is 91.89, with extremes of 98.62 and 57.04. About 55 of the 283 samples from the United States molded in storage before analysis and in a few cases started to ferment. If the analytical results on these had been excluded, the average percentage of sucrose would be 94.36 instead of 91.89. For sap sirups the average figure for sucrose when calculated to dry basis is 95.18 per cent.

INVERT SUGAR.

The extreme percentages of invert sugar in the United States are 37.30 and 0.09, with an average percentage of 5.46, which would be 3.09 per cent if the results of the moldy sugar were not included. This increase, about 50 per cent higher than in the case of sap sirups, occurs because of the inversion of sucrose due to the extra concentration and heat when a sap sirup is made into a sugar. About 30 per cent of the samples have less than 1 per cent of invert sugar, whereas 53 per cent of corresponding samples of sap sirup have less than 1 per cent of invert sugar.

Table XII shows that where large quantities of reducing sugars are present in maple sugar the sucrose equivalent of 1 per cent reducing sugar is 0.30, which is very close to that of true invert sugar of equal parts of dextrose and levulose, but where small percentages of reducing sugars are present, there seems to be a large excess of levulose, and in many cases a levorotatory substance other than levulose is indicated. This was also noted with sap sirup.¹

TABLE XII.—Comparison of sucrose equivalents of 1 per cent of reducing sugar when large and small amounts are present.

| Serial No. | Reducing sugar calculated as invert. | Difference in direct polarization and in sucrose by Clerget. | Sucrose equivalent of 1 per cent reducing sugar. |
|---|--------------------------------------|--|--|
| <i>Large amounts of reducing sugar:</i> | | | |
| 6459..... | 9.61 | 3.46 | 0.37 |
| 6545..... | 7.83 | 3.35 | .43 |
| 6598..... | 9.49 | 4.52 | .47 |
| 6624..... | 7.70 | 3.94 | .51 |
| 6700..... | 7.19 | 3.71 | .51 |
| 6718..... | 14.27 | 6.16 | .43 |
| 6876..... | 6.92 | 3.00 | .43 |
| 6968..... | 11.54 | 5.28 | .45 |
| 8438..... | 7.27 | 3.02 | .41 |
| 8446..... | 8.25 | 2.20 | .26 |
| <i>Small amounts of reducing sugar:</i> | | | |
| 7510..... | 0.66 | 2.67 | 4.04 |
| 7518..... | .41 | 2.57 | 6.26 |
| 7525..... | .58 | 2.77 | 4.77 |
| 7546..... | .75 | 2.07 | 2.76 |
| 7548..... | .22 | 1.84 | 7.37 |
| 8344..... | .65 | 1.00 | 1.54 |
| 8448..... | .66 | 2.02 | 3.06 |
| 8472..... | .96 | 1.70 | 1.77 |
| 8457..... | .78 | 1.80 | 2.31 |
| 8462..... | .51 | 1.30 | 2.55 |

ASH.

Total ash.—In the United States samples the average ash content is 0.95 per cent, with extremes of 1.66 and 0.76 per cent, while with Canada included the average is 0.98 per cent, with extremes of 1.70 and 0.76. The average for sap sirups for the United States is 1.02 per cent, with extremes of 1.68 and 0.68. Including Canada, the

¹ U. S. Dept. Agr., Bur. of Chem. Bul. 134, p. 65.

average is 1 per cent, with the same extremes. Grouping the individual determinations for ash by States and by 0.05 and 0.1 per cent differences, the results in Table XIII are obtained.

TABLE XIII.—Total ash content of sugar, by locality.

| Ash content. | Number of samples. | | | | | | | | | | | | Per-cent-
age of
samples. |
|-------------------|--------------------|-----|-----|-------|-------|-------|-------|----------------|-----|-----|----------------|----------------|---------------------------------|
| | Ind. | Me. | Md. | Mass. | Mich. | N. H. | N. Y. | Ohio. | Pa. | Vt. | W. Va. | Canada. | |
| <i>Per cent.</i> | | | | | | | | | | | | | |
| 0.00 to 0.76..... | | | | | | | | ¹ 1 | | | | ¹ 1 | 2 0.7 |
| .77 to .79..... | | 1 | 1 | | 4 | | 7 | 2 | 7 | 8 | | 3 | 33 9.1 |
| .80 to .84..... | 1 | | 3 | | 4 | 4 | 5 | 5 | 8 | 19 | | 7 | 56 15.4 |
| .85 to .89..... | 2 | | 1 | 1 | 2 | 2 | 12 | 3 | 2 | 7 | | 7 | 39 10.7 |
| .90 to .94..... | 3 | 1 | 3 | 4 | 6 | 3 | 11 | 7 | 4 | 7 | | 7 | 56 15.4 |
| .95 to .99..... | 3 | 2 | 1 | 4 | 4 | 2 | 9 | 6 | 4 | 6 | | 10 | 51 14.0 |
| 1.00 to 1.09..... | 3 | | | 5 | 2 | | 10 | 2 | 5 | 9 | 1 | 11 | 48 13.2 |
| 1.10 to 1.19..... | 3 | | 2 | | 1 | 1 | | 3 | 8 | 2 | 1 | 15 | 36 9.9 |
| 1.20 to 1.29..... | 2 | | | | | | 1 | 1 | 5 | 4 | | 9 | 22 6.0 |
| 1.30 to 1.39..... | | | | | | | 1 | | | | 1 | 4 | 6 1.6 |
| 1.40 to 1.49..... | 1 | | | | | | 1 | 1 | | 1 | 3 | 3 | 9 2.5 |
| 1.50 to 1.59..... | 1 | | | | | | | | | | | 2 | 3 .8 |
| 1.60 to 1.70..... | | | | | | | | | | | ² 1 | ³ 1 | 2 .7 |
| Total..... | 19 | 4 | 11 | 14 | 23 | 12 | 56 | 31 | 43 | 63 | 7 | 80 | 363 100.0 |

¹ 0.76.

² 1.66.

³ 1.70.

The largest number of samples have a content of ash ranging from 0.80 to 1.10 per cent, and nearly 88 per cent of the samples range from 0.77 to 1.20 per cent. The lowest ash content found in this examination, 0.76 per cent, was obtained in a sample from Ohio and in one from Canada. In some of the experimental work, however, ash contents as low as 0.72 per cent were found. These total ash figures may be considered abnormal, as they were found in sirup the lead number, malic acid value, and insoluble ash content of which were far above the minimum figures.

TABLE XIV.—Comparison of percentage of samples of sap and sugar sirup with varying ash content.

| Ash content. | Maple-sap sirup. | Maple-sugar sirup. | Ash content. | Maple-sap sirup. | Maple-sugar sirup. |
|-------------------|------------------|--------------------|-------------------|------------------|--------------------|
| <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> |
| 0.00 to 0.76..... | 0.2 | 0.7 | 1.10 to 1.19..... | 12.3 | 9.9 |
| .77 to .79..... | 3.7 | 9.1 | 1.20 to 1.29..... | 6.0 | 6.0 |
| .80 to .84..... | 11.2 | 15.4 | 1.30 to 1.39..... | 3.7 | 1.6 |
| .85 to .89..... | 11.0 | 10.7 | 1.40 to 1.49..... | .4 | 2.5 |
| .90 to .94..... | 17.7 | 15.4 | 1.50 to 1.59..... | .6 | .8 |
| .95 to .99..... | 12.4 | 14.0 | 1.60 to 1.70..... | 1.0 | .7 |
| 1.00 to 1.09..... | 19.8 | 13.2 | | | |

The same percentage (88.4) of samples in both kinds of sirup have ash contents up to 1.20 per cent, although 36 per cent of the sugar samples and 26 per cent of the sap sirups have an ash content between 0.77 and 0.89 per cent. The appearance of the ash was not regular, a few samples being very green, while many were white or light gray. The appearance of the ash depends upon the method of burning.

Soluble and insoluble ash.—The insoluble ash in the United States samples shows an average figure of 0.33 per cent, with extremes of 0.81 and 0.21 per cent, but when Canada is included, the average figure is 0.36 per cent, with extremes of 1 and 0.21 per cent. These again are somewhat lower than the figures obtained for sap sirup. One sample from Michigan, one from Ohio, and one from Pennsylvania had only 0.22 per cent of insoluble ash, and another from Pennsylvania had 0.21 per cent. The total ash in each of these instances was not low, but was near the minimum line. The results obtained by grouping the samples by localities and dividing the insoluble ash contents into classes by 0.10 per cent are given in Table XV.

TABLE XV.—*Insoluble ash content of sugar, by locality.*

| Insoluble ash content. | Number of samples. | | | | | | | | | | | | | Percentage of samples. |
|------------------------|--------------------|-----|-----|-------|-------|-------|-------|-------|-----|-----|--------|---------|--------|------------------------|
| | Ind. | Me. | Md. | Mass. | Mich. | N. H. | N. Y. | Ohio. | Pa. | Vt. | W. Va. | Canada. | Total. | |
| <i>Per cent.</i> | | | | | | | | | | | | | | |
| Below 0.23... | | | | | 1 | | | 1 | 2 | | | | 4 | 1.4 |
| 0.23 to 0.29... | 4 | 1 | 1 | 4 | 8 | | 7 | 6 | 4 | | | | 35 | 9.6 |
| .24 to .29... | 5 | 1 | 5 | 8 | 6 | 6 | 29 | 5 | 14 | 18 | | 15 | 112 | 30.8 |
| .30 to .39... | 4 | 2 | 4 | 2 | 7 | 5 | 15 | 17 | 14 | 24 | | 18 | 112 | 30.8 |
| .40 to .49... | 2 | | 1 | | 1 | 1 | 4 | 2 | 6 | 7 | 3 | 22 | 49 | 13.5 |
| .50 to .59... | 3 | | | | | | | | 2 | 8 | 2 | 9 | 24 | 6.6 |
| .60 to .69... | | | | | | | 1 | | 1 | 5 | 2 | 8 | 17 | 4.7 |
| .70 to .79... | 1 | | | | | | | | | | | 5 | 6 | 1.6 |
| .80 to .89... | | | | | | | | | | 1 | | 2 | 3 | 0.8 |
| .90 to .99... | | | | | | | | | | | | | | |
| 1.00 to 1.09... | | | | | | | | | | | | 1 | 1 | 0.2 |
| Total... | 19 | 4 | 11 | 14 | 23 | 12 | 56 | 31 | 43 | 63 | 7 | 80 | 363 | 100.0 |

¹ 0.22.² 0.21, 0.22.³ 0.81.⁴ 1.00.

From this it is seen that 72.6 per cent of the samples have an insoluble ash content of less than 0.40 per cent. In Canada 59 per cent of the samples have a higher number than that, while all the West Virginia samples have a higher insoluble ash content than 0.40 per cent. The other States show their largest figures below 0.40 per cent.

Percentage of soluble ash divided by percentage of insoluble ash.—The average figure is 1.69; that is, the percentage of insoluble ash is about 55 per cent of the soluble ash. The highest is 4.07 and the lowest, 0.43. Among the sap sirups some 29 samples, or 6 per cent, showed a ratio below 1.0; among the sugar sirups 8 per cent were found with this low ratio. These samples were confined to the State of Vermont and to Canada. From Table XVI, showing the data by groups of 0.01 and 0.25, it is seen that the largest percentage of samples falls between 1.25 and 2.75.

TABLE XVI.—Soluble and insoluble ash content of sugar, by locality.

| Soluble ash divided by insoluble ash. | Number of samples. | | | | | | | | | | | | Percentage of samples. |
|---------------------------------------|--------------------|-----|-----|-------|-------|-------|----------------|-------|-----|-----|--------|----------------|------------------------|
| | Ind. | Me. | Md. | Mass. | Mich. | N. H. | N. Y. | Ohio. | Pa. | Vt. | W. Va. | Canada. | |
| <i>Per cent.</i> | | | | | | | | | | | | | |
| 0.0 to 0.59 | | | | | | | | | | | | ¹ 2 | 2 0.7 |
| .60 to .69 | | | | | | | | | | 2 | | 1 | 3 .8 |
| .70 to .79 | | | | | | | | | | 4 | | 6 | 10 2.7 |
| .80 to .89 | | | | | | | | | | 5 | | 3 | 8 2.2 |
| .90 to .99 | | | | | | | | | | 2 | | 4 | 6 1.6 |
| 1.00 to 1.24 | 3 | | 2 | | | 1 | 3 | 3 | 1 | 7 | | 13 | 33 9.1 |
| 1.25 to 1.49 | 1 | | | | 1 | 4 | 7 | 1 | 8 | 6 | 5 | 13 | 46 12.7 |
| 1.50 to 1.74 | 1 | | | | 3 | | 3 | 5 | 6 | 12 | | 8 | 38 10.4 |
| 1.75 to 1.99 | | 1 | 2 | | 3 | 1 | 7 | 3 | 2 | 9 | 1 | 8 | 37 10.2 |
| 2.00 to 2.24 | 2 | 1 | 3 | 2 | 3 | 2 | 6 | 5 | 9 | 10 | 1 | 10 | 54 14.8 |
| 2.25 to 2.49 | 4 | 2 | 3 | 1 | 4 | 1 | 8 | 5 | 10 | 5 | | 4 | 47 13.0 |
| 2.50 to 2.74 | 3 | | 1 | 3 | 4 | 3 | 12 | 7 | 3 | | | 7 | 43 11.8 |
| 2.75 to 2.99 | 4 | | | 3 | 1 | | 5 | 1 | 3 | 1 | | | 18 5.0 |
| 3.00 to 3.49 | | | | 5 | 4 | | 3 | 1 | | | | 1 | 14 3.8 |
| 3.50 to 3.99 | 1 | | | | | | 1 | | 1 | | | | 3 .8 |
| 4.00 to 4.10 | | | | | | | ² 1 | | | | | | 1 .4 |
| Total.. | 19 | 4 | 11 | 14 | 23 | 12 | 56 | 31 | 43 | 63 | 7 | 80 | 363 100.0 |

¹ 0.43, 0.57.

² 4.07.

Alkalinity of soluble and insoluble ash.—This determination is expressed in the number of cubic centimeters of tenth-normal acid necessary to neutralize the ash of 100 grams of sirup. For insoluble ash, which is chiefly calcium carbonate, the average figure is 87 cc, the extremes being 190 and 31. Since 1 cc of tenth-normal acid is equal to 0.005 gram of calcium carbonate, the 87 cc are equivalent to 0.435 gram of calcium carbonate. The actual average percentage of insoluble ash is 0.36, which is 0.07 gram lower than that calculated from the alkalinity. The average figure for soluble ash is 75 cc, with extremes of 140 and 42. Considering the soluble ash to be potassium carbonate, the 75 cc would equal 0.518 gram of potassium carbonate. The average percentage of soluble ash is 0.62, which is 0.11 gram higher than that calculated from the alkalinity. This may be accounted for by the presence of alkaline salts other than potash.

LEAD NUMBER.

The average lead numbers for the individual States vary to a great extent, as shown in Table XVII:

TABLE XVII.—Average of the Winton and Ross lead numbers, by States.

| No. | Locality. | Winton lead number. | Locality. | Ross lead number. |
|-----|---------------|---------------------|---------------|-------------------|
| 1 | West Virginia | 3.99 | West Virginia | 4.49 |
| 2 | Indiana | 3.04 | Indiana | 3.73 |
| 3 | Canada | 3.04 | | (¹) |
| 4 | Pennsylvania | 3.84 | Pennsylvania | 3.34 |
| 5 | Ohio | 2.74 | Ohio | 3.29 |
| 6 | Vermont | 2.70 | Vermont | 3.39 |
| 7 | Massachusetts | 2.67 | Massachusetts | 3.55 |
| 8 | Maryland | 2.61 | Maryland | 2.99 |
| 9 | Michigan | 2.52 | Michigan | 3.33 |
| 10 | New Hampshire | 2.50 | New Hampshire | 3.50 |
| 11 | Maine | 2.43 | Maine | 3.40 |
| 12 | New York | 2.42 | New York | 3.05 |

¹ Canada is not included, as this determination was not made on all the samples.

West Virginia and Indiana stand at the top in each determination, the rest of the localities varying in their places. It is noted that in each case the Ross lead number is higher than the Winton. The average for the Winton number in the United States samples is 2.68, with extremes of 4.95 and 1.85. Including the results from the Canadian samples the average is 2.76, with the same extremes. With the Ross number, the United States average is 3.34, with extremes of 5.90 and 2.20. The increase in lead number by the Ross method averages 0.58.

Grouping the lead number by localities into divisions varying by 0.25 and placing the samples with these figures in such groups, the results in Table XVIII are obtained.

TABLE XVIII.—*Lead number of sugar, by locality.*

| Lead number. | Number of samples. | | | | | | | | | | | | | Per-centage of samples. |
|-------------------|--------------------|-----|-----|-------|-------|------|------|-------|-----|-----|--------|---------|--------|-------------------------|
| | Ind. | Me. | Md. | Mass. | Mich. | N.H. | N.Y. | Ohio. | Pa. | Vt. | W. Va. | Canada. | Total. | |
| Winton: | | | | | | | | | | | | | | |
| 0.00 to 1.84..... | | | | | | | | | | | | | | |
| 1.85 to 1.99..... | | | | | 3 | 2 | 3 | 2 | 4 | 7 | | 1 | 22 | 6.1 |
| 2.00 to 2.24..... | 1 | | 3 | 1 | 4 | 1 | 16 | 7 | 9 | 11 | | 3 | 56 | 15.5 |
| 2.25 to 2.49..... | 1 | 2 | 3 | 5 | 6 | 5 | 16 | 3 | 6 | 12 | | 15 | 74 | 20.5 |
| 2.50 to 2.74..... | 4 | 1 | 1 | 2 | 3 | 1 | 14 | 6 | 2 | 5 | | 10 | 49 | 13.6 |
| 2.75 to 2.99..... | 5 | | 1 | 3 | 3 | 2 | 4 | 3 | 4 | 6 | | 7 | 38 | 10.5 |
| 3.00 to 3.24..... | 3 | | 3 | 2 | 2 | | 1 | 3 | 6 | 5 | 1 | 15 | 41 | 11.3 |
| 3.25 to 3.49..... | 1 | | | 1 | 2 | 1 | | 2 | 1 | 7 | 1 | 14 | 30 | 8.3 |
| 3.50 to 3.74..... | 1 | | | | | | 1 | 3 | 4 | 6 | 1 | 8 | 24 | 6.6 |
| 3.75 to 3.99..... | 1 | 1 | | | | | | 1 | 5 | 2 | | 4 | 12 | 3.9 |
| 4.00 to 4.49..... | 2 | | | | | | | 1 | 2 | 1 | 2 | 3 | 11 | 3.1 |
| 4.50 to 5.00..... | | | | | | | | | | | 2 | | 2 | 0.6 |
| Total..... | 19 | 4 | 11 | 14 | 23 | 12 | 155 | 31 | 43 | 162 | 7 | 80 | 361 | 100.0 |
| Ross: | | | | | | | | | | | | | | |
| 0.00 to 2.24..... | | | | | | | | 1 | 1 | 1 | | | 3 | 1.1 |
| 2.25 to 2.49..... | | | 2 | | | | 3 | 2 | 4 | 2 | | | 13 | 4.6 |
| 2.50 to 2.74..... | | 1 | | 1 | 1 | 1 | 7 | 3 | 6 | 7 | | | 29 | 10.3 |
| 2.75 to 2.99..... | | | 1 | | 3 | 1 | 14 | 4 | 10 | 7 | | | 40 | 14.2 |
| 3.00 to 3.24..... | 4 | | 3 | 3 | 6 | 1 | 15 | 4 | 1 | 13 | | | 50 | 17.8 |
| 3.25 to 3.49..... | | | 1 | 6 | 6 | 4 | 10 | 5 | 3 | 6 | 1 | | 42 | 14.9 |
| 3.50 to 3.74..... | 8 | 2 | 1 | 3 | 4 | | 3 | 6 | 6 | 5 | 1 | | 39 | 13.9 |
| 3.75 to 3.99..... | 2 | 1 | 1 | 1 | 1 | 3 | 2 | 4 | 2 | 11 | | | 28 | 10.0 |
| 4.00 to 4.24..... | 3 | | | | 2 | | | | 2 | 6 | 1 | | 14 | 5.0 |
| 4.25 to 4.49..... | | | | | | 2 | | 1 | 4 | 2 | 1 | | 10 | 3.6 |
| 4.50 to 4.74..... | 2 | | | | | | | 1 | 2 | 3 | 1 | | 9 | 3.1 |
| 4.75 to 4.99..... | | | | | | | | | 2 | | 1 | | 3 | 1.1 |
| 5.00 to 6.00..... | | | | | | | | | | | 1 | | 1 | 0.4 |
| Total..... | 19 | 4 | 11 | 14 | 23 | 12 | 254 | 31 | 43 | 63 | 7 | | 281 | 100.0 |

¹ Determinations not made on one sample.² Two not made.

In the total column of the Winton number, most of the samples have a number between 2.00 and 3.50. In some States the variation is rather small; for example, New York shows 83 per cent of samples between 2.00 and 2.74, Indiana 70 per cent of samples between 2.50 and 3.24 while in West Virginia no samples were found with a number below 3.00.

With the Ross number the largest percentage of samples falls between 2.50 and 3.99, New York showing 72 per cent between 2.75

and 3.49, Indiana nearly 50 per cent of samples with a lead number between 3.50 and 3.74, and West Virginia no samples below 3.25.

Ross¹ indicates that the excess of both lead subacetate and sugar exert a marked effect upon the lead subacetate precipitate and shows that the effect of the excess of sugar is relatively greater. In the procedure for his method potassium sulphate is added to the solution before the lead subacetate to overcome the solvent action of the sugar upon the lead precipitate. Ross believes this solvent action to be the cause of the lead number of mixtures of maple and cane sirup not being proportional to the percentage of maple present. The figures by Ross lead number given herein, however, apply only to sirups having a density of approximately 65 per cent solids which were made up from pure maple sugar, and the application of lead number determinations to mixtures of maple and cane sugar sirup has not been entered into in connection with this bulletin. In Table XIX the increase of the individual samples is grouped by differences of 0.10 and by States.

TABLE XIX.—*Differences between Winton and Ross lead numbers.*

| Lead number. | Number of samples. | | | | | | | | | | | Percentage of samples. | |
|------------------------------------|--------------------|-----|-----|-------|-------|-------|-------|-------|-----|-----|--------|------------------------|--------|
| | Ind. | Me. | Md. | Mass. | Mich. | N. H. | N. Y. | Ohio. | Pa. | Vt. | W. Va. | | Total. |
| Winton higher than Ross..... | | | | | | | | 2 | | | | 2 | 0.7 |
| Winton and Ross equal..... | | | | | | | | | | 1 | | 1 | .3 |
| Ross higher by less than 0.10..... | | | | | | | 1 | 3 | 4 | | 1 | 9 | 3.2 |
| Ross higher by more than: | | | | | | | | | | | | | |
| 0.10..... | 1 | | 2 | | | | | 2 | 4 | | 1 | 10 | 3.6 |
| .20..... | | | 3 | 1 | | | 2 | 3 | 2 | 1 | 1 | 13 | 4.6 |
| .30..... | | | 2 | 1 | 1 | | 5 | 2 | 4 | 3 | 2 | 20 | 7.1 |
| .40..... | 2 | 1 | 1 | 1 | | | 11 | 1 | 8 | 8 | 1 | 34 | 12.2 |
| .50..... | | | 2 | 3 | 2 | | 10 | 1 | 8 | 11 | | 37 | 13.2 |
| .60..... | 3 | | | 2 | 4 | | 7 | 4 | 5 | 6 | | 31 | 11.1 |
| .70..... | 4 | | | 2 | 6 | 3 | 5 | 4 | 4 | 12 | | 40 | 14.3 |
| .80..... | 6 | 1 | | 1 | 5 | 3 | 7 | 3 | 1 | 10 | | 37 | 13.2 |
| .90..... | 2 | 1 | 1 | 1 | 3 | 4 | | 4 | 1 | 6 | 1 | 24 | 8.6 |
| 1.00..... | 1 | | | 1 | 2 | | 2 | 1 | | | | 7 | 2.5 |
| 1.10..... | | | | 1 | | 1 | 3 | 1 | | 2 | | 8 | 2.9 |
| 1.20..... | | 1 | | | | | | | | 2 | | 3 | 1.1 |
| 1.30..... | | | | | | 1 | 1 | | 1 | | | 3 | 1.1 |
| 1.40..... | | | | | | | | | 1 | | | 1 | .3 |
| Total..... | 19 | 4 | 11 | 14 | 23 | 12 | 54 | 31 | 43 | 62 | 7 | 280 | 100.0 |
| Difference: | | | | | | | | | | | | | |
| Average..... | 69 | 93 | 38 | 68 | 81 | 100 | 63 | 55 | 50 | 69 | 50 | | |
| Maximum..... | 112 | 126 | 92 | 116 | 104 | 133 | 137 | 121 | 142 | 129 | 95 | | |
| Minimum..... | 48 | 49 | 16 | 29 | 35 | 74 | 8 | | 3 | | 6 | | |

The increase varies greatly in the samples, the greatest increase being 1.42 and the least 0.15. Eighty per cent of the samples show an increase of from 0.30 to 1. Table XX gives the results of samples that show little difference between the two numbers, from which it is seen that factors other than the solubility of the lead precipitate in the sugar solution enter into the amount of the lead number.

¹ U. S. Dept. Agr., Bur., Chem. Cir. 53.

TABLE XX.—*Samples with Winton and Ross lead numbers showing slight variation.*

| State. | Serial No. | Lead numbers. | | |
|--------------------|------------|---------------|-------|-------------|
| | | Winton. | Ross. | Difference. |
| Ohio..... | 6315 | 3.61 | 3.57 | —0.04 |
| Do..... | 6318 | 3.47 | 3.32 | — .15 |
| Vermont..... | 6788 | 3.58 | 3.58 | .00 |
| New York..... | 7561 | 2.37 | 2.45 | + .08 |
| Ohio..... | 6313 | 3.53 | 3.62 | + .09 |
| Do..... | 6373 | 2.16 | 2.22 | + .06 |
| Do..... | 6374 | 2.23 | 2.25 | + .02 |
| Pennsylvania..... | 6882 | 3.22 | 3.30 | + .08 |
| Do..... | 6884 | 2.77 | 2.86 | + .09 |
| Do..... | 6864 | 3.68 | 3.71 | + .03 |
| Do..... | 6872 | 3.69 | 3.74 | + .05 |
| West Virginia..... | 7503 | 4.64 | 4.70 | + .06 |

MALIC ACID VALUE.

The average of all determinations was 0.93, with extremes of 1.72 and 0.51. This average is a little below that obtained on sap sirups, 1.01, and the extremes are not as far apart as in sap sirups. The results by localities and groups of 0.10 and 0.25 are tabulated in Table XXI.

TABLE XXI.—*Malic acid value of sugar, by locality.*

| Malic acid value. | Number of samples. | | | | | | | | | | | | | Per-centage of sam-ples. |
|-------------------|--------------------|-----|-----|--------------------|-------|------|------|---------------------------|----------------|----------------|--------|----------|------------------|--------------------------|
| | Ind. | Me. | Md. | Mass. | Mich. | N.H. | N.Y. | Ohio. | Pa. | Vt. | W. Va. | Can-ada. | Total. | |
| 0.00 to 0.59..... | | | | | | | | | ¹ 1 | ² 1 | | | 2 | 0.7 |
| .60 to .69..... | | 1 | 1 | | 6 | | 3 | 2 | 3 | 8 | | 2 | 26 | 7.2 |
| .70 to .79..... | 2 | | 5 | 1 | 2 | 4 | 14 | 8 | 7 | 7 | | 9 | 59 | 16.3 |
| .80 to .99..... | 8 | 3 | 3 | 9 | 12 | 4 | 30 | 7 | 16 | 26 | | 25 | 143 | 39.2 |
| 1.00 to 1.24..... | 7 | | 2 | 4 | 3 | 4 | 9 | 12 | 14 | 19 | 2 | 29 | 105 | 29.0 |
| 1.25 to 1.49..... | 2 | | | | | | | 1 | 2 | 2 | 2 | 14 | 23 | 6.3 |
| 1.50 to 1.74..... | | | | | | | | | | | 3 | 1 | 4 | 1.3 |
| Total... | 19 | 4 | 11 | 14 | 23 | 12 | 56 | ³ 30 | 43 | 63 | 7 | 80 | ³ 362 | 100.0 |
| | ¹ 0.59. | | | ² 0.51. | | | | ³ One missing. | | | | | | |

¹ 0.59.² 0.51.³ One missing.

The largest number of samples falls in the groups from 0.70 to 1.24. Two samples show figures below 0.60, one from Pennsylvania with a value of 0.59, and one from Vermont with a value of 0.51, while in the sap sirup 6 out of the 480 showed values below 0.60, one being as low as 0.21.

TANNIN REACTION.

The ferric-chlorid test showed indications of tannin in nearly one-third of the samples, being very strong in 10 samples. In all cases where tannin was noted the color of the sirup was dark, and in most of these the flavor was poor. The fact that tannin was found in a larger number of the sugar-sirup samples than of the sap-sirup samples may be accounted for by the fact that less care was taken in the preparation of the maple sugar than in that of the sap sirup. Many

tests have been made of the fresh sap in different bushes with ferric chlorid, but in no case has a coloration due to tannin been noted. Tannin is present in sap that has stood during a rainstorm, as well as in dirty sap.

UNDETERMINED MATTER.

As this is a difference figure, it is influenced by the accuracy of the other determinations. The highest figure noted for the United States samples was 5.84, and the minimum was 0, the average being 1.70. This difference is almost entirely accounted for when ash, which is weighed as a carbonate, is calculated to a malate, in which condition it is supposed to occur naturally.

CANADIAN MAPLE SUGARS.

Comparison of Canadian sap sirups with those from the United States showed that they were darker in color and gave lower analytical results.¹ The same comparison on maple sugars shows that on an average the analytical figures for Canadian samples are slightly higher than those for the United States. Table XXII gives the average results.

TABLE XXII.—*Comparison of analytical results for Canadian and United States sugar.*

| Determination. | United States samples (283). | Canadian samples (80). | Determination. | United States samples (283). | Canadian samples (80). |
|-------------------------|------------------------------|------------------------|------------------------------|------------------------------|------------------------|
| Sucrose.....per cent.. | 91.89 | 86.48 | Insoluble ash.....per cent.. | 0.33 | 0.45 |
| Invert sugar.....do.... | 5.46 | 8.76 | Soluble ash.....do..... | .62 | .61 |
| Undetermined.....do.... | 1.70 | 3.70 | Winton lead number..... | 2.68 | 3.04 |
| Total ash.....do..... | .95 | 1.06 | Ross lead number..... | 13.34 | 23.66 |
| | | | Malic acid value..... | .91 | 1.03 |
| Total.....do..... | 100.00 | 100.00 | | | |

¹ Average of determinations on 282 samples.

² Average of determinations on 26 samples. Determination not made on rest of the 80 samples.

The darker color of the Canadian samples was due to the process of manufacture rather than to the environment or climate, for products as light colored as those manufactured in the United States are made in Canada. Crudeness in the process leads to dark, strong-flavored products, which are of no value for consumption in that condition, but find a market in mixtures of maple and sugar sirups or for giving flavor to a sirup.

The Canadian samples may be grouped into three divisions, those coming from Beauce and the surrounding townships, those from the region below Montreal, centered around Sherbrook and Waterloo, and those above Montreal in Joliette Township. Figure 1 shows the relative location of these townships, as well as the average figures for the important analytical determinations.

From this it is seen that the figures for the Beauce district are a little higher than those for the other two districts, the region below Montreal giving the lowest figures and that above Montreal the next lowest. This is apparently the direct opposite of the tendency of the sugar sirup of the United States.

EFFECT OF ENVIRONMENT ON THE COMPOSITION OF MAPLE SUGAR.

In the case of sap sirup, there is a relationship between the location of States and the composition of the product. Taking the average determinations for the States and localities in some of the

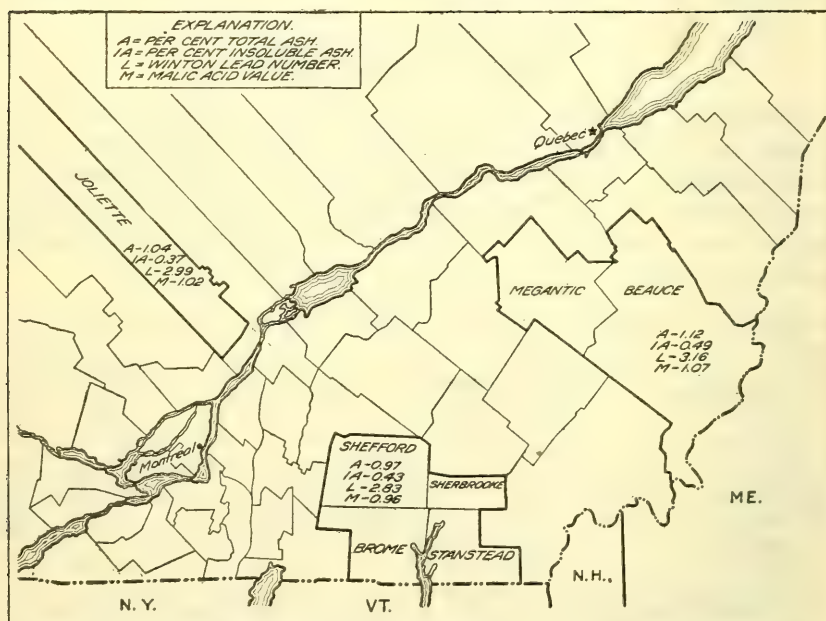


FIG. 1.—Map showing effect of environment on analytical results of maple sugar, Canada.

States, as one goes north there is a lower figure for total ash, lead number, and malic acid value. Tabulating the results of the maple sugar work in this way, the same general tendency is noted.

TABLE XXIII.—Average analyses of samples, by localities.

| Determination. | Analyses. | | | | | | | | | | | |
|-------------------------|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|---------|
| | W. Va. | Ind. | Ohio. | Md. | Pa. | Mich. | Mass. | N. Y. | Vt. | N. H. | Me. | Canada. |
| Sucrose.....per cent. | 91.15 | 90.16 | 89.98 | 95.38 | 92.92 | 92.00 | 93.17 | 96.04 | 88.39 | 89.54 | 94.11 | 86.48 |
| Invert sugar.....do. | 6.27 | 5.64 | 6.52 | 1.89 | 4.92 | 4.63 | 5.44 | 2.33 | 8.37 | 7.71 | 4.06 | 8.76 |
| Total ash.....do. | 1.37 | 1.08 | .95 | .91 | .97 | .90 | .98 | .92 | .92 | .91 | .90 | 1.06 |
| Insoluble ash.....do. | .53 | .36 | .31 | .31 | .33 | .28 | .26 | .30 | .38 | .32 | .29 | .45 |
| Winton lead number..... | 3.99 | 3.04 | 2.74 | 2.61 | 2.84 | 2.52 | 2.67 | 2.42 | 2.70 | 2.50 | 2.43 | 3.04 |
| Ross lead number..... | 4.49 | 3.73 | 3.29 | 2.99 | 3.34 | 3.33 | 3.35 | 3.05 | 3.39 | 3.50 | 3.40 | ..... |
| Malic acid value..... | 1.38 | 1.00 | .92 | .85 | .93 | .83 | .99 | .87 | .92 | .92 | .82 | 1.03 |

The southern maple-producing States, West Virginia, Indiana, Ohio, Pennsylvania, and Maryland, show higher figures than the northern States, Vermont, New Hampshire, Maine, and Michigan. This relationship becomes more evident when the figures are inserted in a map of the United States in the region from which the samples come. In the western group, West Virginia, Maryland, Pennsylvania, Ohio, Indiana, and Michigan, the sectional differences are very marked. With the exception of the Maryland figures, the drop in all determinations as one goes north is very marked. From West

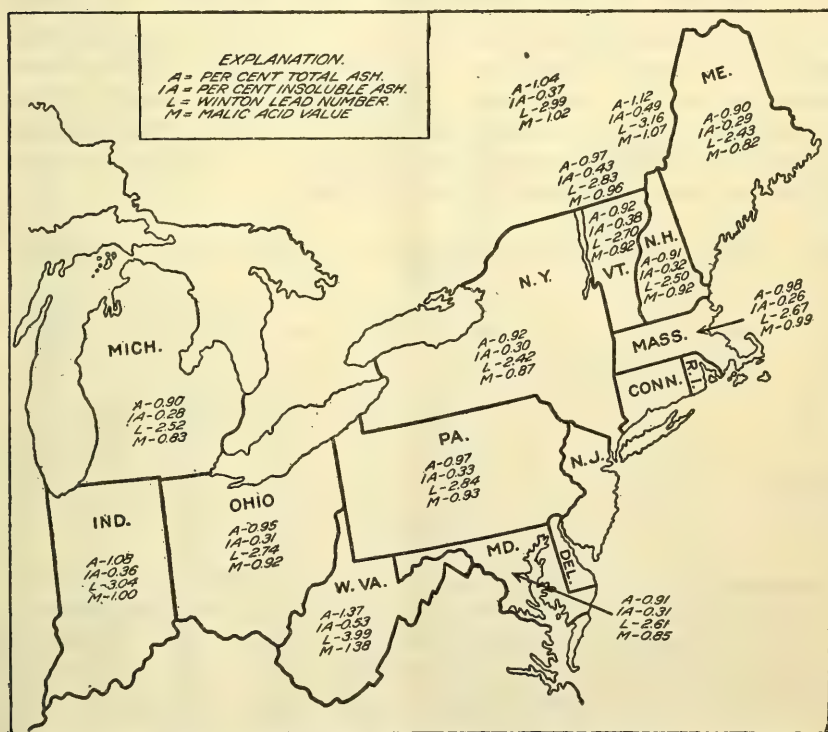


FIG. 2.—Map showing effect of environment on analytical results of maple sugar, United States.

Virginia to Michigan there is a drop of 0.47 per cent in ash, of 0.25 per cent in insoluble ash, of 1.47 in Winton lead number and 1.16 in Ross lead number, and of 0.55 in the malic acid value. In the eastern section, comprising New York, Massachusetts, Vermont, New Hampshire, and Maine, the drop as one goes north is not so great. From Massachusetts to Maine, the drop in total ash is 0.08 per cent, in insoluble ash none, in Winton lead number 0.24, in Ross lead number none, and in malic acid value 0.17.

It is evident, then, that environment plays some part in the composition of maple sugar.

CHANGES IN COMPOSITION AND COLOR FROM SAP SIRUP TO SUGAR SIRUP.

The sirup from maple sugar has a more even color and flavor than sap sirup, due to the mixing of various grades of maple sugar. It is much darker in color than that of the original sap sirup, and the taste is greatly changed, although no comparative figures along this line are available.

Ten samples of the sap sirup were collected and analyzed; a portion of the sirup was then concentrated in a glass vessel over a lamp to the sugaring-off point, stirred, and allowed to cool. The sugar so produced was again dissolved in water to the consistency of commercial sap sirup, filtered, and analyzed. In this additional concentration, in most cases, very little precipitation occurred. There was enough, however, to make the sugar sirup cloudy, but this soon settled when allowed to stand. For comparison, the figures obtained on analysis were calculated to the dry basis.

TABLE XXIV.—Changes in color and composition from maple-sap sirup to maple-sugar sirup.

| Kind of sirup. | Color. | Sucrose. | Invert sugar. | Ash. | Insoluble ash. | Lead number. | Malic acid value. |
|------------------|--------|------------------|------------------|------------------|------------------|--------------|-------------------|
| | | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | | |
| Sap sirup..... | 10 | 93.83 | 2.68 | 0.78 | 0.28 | 2.19 | 0.75 |
| | 7 | 96.80 | .93 | .84 | .24 | 2.26 | .84 |
| | 7 | 96.64 | .45 | .90 | .23 | 2.00 | .77 |
| | 9 | 95.10 | 1.84 | .94 | .40 | 2.84 | 1.05 |
| | 7+ | 95.43 | 1.20 | 1.07 | .46 | 3.13 | 1.16 |
| | 9 | 95.23 | .71 | .87 | .27 | 2.28 | .87 |
| | 8 | 94.26 | 1.43 | .83 | .34 | 2.56 | .85 |
| | 8 | 92.93 | 2.63 | .82 | .36 | 2.70 | .87 |
| | 9+ | 95.15 | .81 | .80 | .26 | 1.93 | .69 |
| | 8 | 95.82 | 1.10 | .82 | .23 | 1.99 | .73 |
| Average..... | 8.2 | 95.12 | 1.48 | .87 | .31 | 2.39 | .86 |
| Sugar sirup..... | 12 | 83.03 | 8.86 | .77 | .22 | 2.04 | .62 |
| | 9 | 96.10 | 1.51 | .81 | .22 | 1.96 | .60 |
| | 9 | 96.18 | 1.07 | .77 | .22 | 2.42 | .61 |
| | 9+ | 94.18 | 3.46 | .80 | .23 | 2.07 | .63 |
| | 9 | 95.24 | 1.49 | .88 | .22 | 2.20 | .66 |
| | 11 | 94.90 | 1.40 | .85 | .23 | 2.11 | .59 |
| | 9 | 95.60 | 1.70 | .79 | .28 | 1.98 | .64 |
| | 9 | 92.88 | 3.68 | .80 | .31 | 2.29 | .69 |
| | .11 | 95.25 | 1.11 | .85 | .22 | 1.96 | .69 |
| | 9 | 96.11 | 1.32 | .83 | .23 | 2.09 | .74 |
| Average..... | 9.7 | 93.95 | 2.56 | .81 | .24 | 2.11 | .65 |

Taking the individual determinations as given in Table XXIV, the color increases in every case, the average increase being two colors. If this concentration had been carried on under commercial conditions, the color would probably have been influenced to a greater extent, for the boiling in this instance was carried on under the best possible conditions, in glass apparatus. In concentration, the percentage of sucrose has decreased in nearly all cases, while at the same time there is an increase in the percentage of invert sugar, showing that longer and higher heating tends to break down the sucrose.

The percentage of ash drops from 0.87 to 0.81 per cent, and of insoluble ash from 0.31 to 0.24 per cent, the lime salts evidently being the ones eliminated. The figures for the lead number show a decrease of 0.28 from 2.39 to 2.11, and the malic acid value decreases from 0.86 to 0.65, all indicating that a malate of lime is precipitated.

MOISTURE IN MAPLE SUGAR.

The percentage of moisture was determined in only a few of the samples of sugars. The percentage varied somewhat, as shown in Table XXV.

TABLE XXV.—*Moisture in maple sugar.*

| Sample No. | Condition. | Moisture. | Sample No. | Condition. | Moisture. |
|--------------|------------------|------------------|-----------------|------------------|------------------|
| | | <i>Per cent.</i> | | | <i>Per cent.</i> |
| Grain sugar: | | | Cake sugar—Con. | | |
| 8413..... | Very dry..... | 0.65 | 8360..... | Medium hard..... | 6.28 |
| 8338..... | Medium dry..... | 3.84 | 8362..... | do..... | 6.46 |
| 8339..... | do..... | 6.65 | 8364..... | do..... | 6.78 |
| 8344..... | do..... | 8.42 | 8366..... | do..... | 9.67 |
| 8333..... | Soft..... | 11.00 | 8367..... | do..... | 7.43 |
| Cake sugar: | | | 8375..... | do..... | 8.50 |
| 8325..... | Hard..... | 4.19 | 8378..... | do..... | 8.31 |
| 8324..... | do..... | 5.28 | 8386..... | do..... | 5.53 |
| 8349..... | do..... | 8.18 | 8430..... | do..... | 6.96 |
| 8350..... | do..... | 7.35 | 8433..... | do..... | 7.08 |
| 8351..... | do..... | 5.87 | 8451..... | do..... | 7.97 |
| 8387..... | Very hard..... | 1.43 | 8452..... | do..... | 9.45 |
| 8460..... | Hard..... | 5.21 | 8454..... | do..... | 8.57 |
| 8500..... | do..... | 7.40 | 8501..... | do..... | 6.22 |
| 8372..... | do..... | 3.15 | 8346..... | Soft..... | 10.79 |
| 8381..... | do..... | 2.10 | 8347..... | do..... | 9.64 |
| 8326..... | Medium hard..... | 8.88 | 8348..... | do..... | 10.41 |
| 8327..... | do..... | 9.21 | 8352..... | do..... | 10.60 |
| 8345..... | do..... | 7.53 | 8353..... | do..... | 10.40 |
| 8354..... | do..... | 7.79 | 8365..... | do..... | 10.66 |
| 8355..... | do..... | 8.24 | 8374..... | do..... | 10.27 |
| 8356..... | do..... | 7.95 | 8434..... | do..... | 9.88 |
| 8358..... | do..... | 6.97 | 8463..... | do..... | 11.20 |
| 8359..... | do..... | 6.32 | 8466..... | do..... | 10.44 |

As the percentage of water increases, the cake becomes softer; but no exact lines can be drawn on moisture content between soft and hard sugar. This depends to a great extent on the moisture content, but also on the chemical composition, that is, on the percentage of invert sugar. In general, sugars having more than 9 per cent of water are soft enough to drain badly. In fact, if most cakes with even 7 per cent of water were allowed to stand for some time there would be an appreciable quantity of drained molasses. In the 47 samples examined, the moisture content varied from 0.65 to 11.20 per cent. A former publication ¹ gives as the maximum for moisture 11 per cent and the minimum 3.05 per cent. Hortvet ² reports samples with 4.27 to 15.67 per cent of moisture, while McGill ³ reports analyses of 83 samples with a moisture content of from 0.06 to 7.06 per cent.

The method proposed by Stanek ⁴ with his tables, using an immersion refractometer, was the one used for this determination. The great value of this method lies in its quick and comparable results.

¹ U. S. Dept. Agr., Bu. Chem. Cir. 40.

² Jour. Amer. Chem. Soc., 26 (1904), p. 1523.

³ Lab. Inland Rev. Dept. Canada Bul. 258.

⁴ Zeit. Zuckerind. Böhmen, 35 (1910), p. 57; 35 (1911), p. 187.

In this method specially standardized 100 cc flasks are used. Upon their necks are etched marks showing where 100 grams of recently boiled distilled water reach, at a temperature of 17.5° C. The correctness of all readings depends on this graduation.

Twenty grams of the sample are weighed and transferred with water to one of these flasks. The sugar is dissolved by shaking, and the flask, after being filled almost to the mark with water, is allowed to stand in a constant temperature bath for 20 or 30 minutes with occasional shaking. The volume is then completed with water of the same temperature, the solution shaken, and a reading taken with the immersion refractometer, the temperature being noted at the same time with an accurate thermometer (better calibrated to one-tenth). If the temperature is any other than 17.5° C., the reading obtained must be corrected by the figures opposite the temperature in Table XXVI. For readings taken at temperatures below 17.5° C. the correction is subtracted, and for readings at temperatures above 17.5° C. the correction is added.

TABLE XXVI.—*Temperature corrections.*¹

| Temperature. | Number to be subtracted. | Temperature. | Number to be added. | Temperature. | Number to be added. | Temperature. | Number to be added. |
|--------------|--------------------------|--------------|---------------------|--------------|---------------------|--------------|---------------------|
| ° C. | | ° C. | | ° C. | | ° C. | |
| 15.0 | 0.72 | 17.6 | 0.03 | 20.2 | 0.82 | 22.8 | 1.62 |
| 15.1 | .70 | 17.7 | .06 | 20.3 | .85 | 22.9 | 1.65 |
| 15.2 | .67 | 17.8 | .09 | 20.4 | .88 | | |
| 15.3 | .64 | 17.9 | .12 | 20.5 | .91 | 23.0 | 1.69 |
| 15.4 | .61 | | | 20.6 | .94 | 23.1 | 1.72 |
| 15.5 | .58 | 18.0 | .15 | 20.7 | .97 | 23.2 | 1.75 |
| 15.6 | .55 | 18.1 | .18 | 20.8 | 1.00 | 23.3 | 1.78 |
| 15.7 | .52 | 18.2 | .21 | 20.9 | 1.03 | 23.4 | 1.81 |
| 15.8 | .49 | 18.3 | .24 | | | 23.5 | 1.85 |
| 15.9 | .46 | 18.4 | .27 | 21.0 | 1.06 | 23.6 | 1.88 |
| | | 18.5 | .30 | 21.1 | 1.09 | 23.7 | 1.91 |
| 16.0 | .44 | 18.6 | .33 | 21.2 | 1.12 | 23.8 | 1.96 |
| 16.1 | .41 | 18.7 | .36 | 21.3 | 1.15 | 23.9 | 1.99 |
| 16.2 | .38 | 18.8 | .39 | 21.4 | 1.18 | | |
| 16.3 | .35 | 18.9 | .42 | 21.5 | 1.22 | 24.0 | 2.03 |
| 16.4 | .32 | | | 21.6 | 1.25 | 24.1 | 2.06 |
| 16.5 | .29 | 19.0 | .45 | 21.7 | 1.28 | 24.2 | 2.09 |
| 16.6 | .26 | 19.1 | .48 | 21.8 | 1.31 | 24.3 | 2.12 |
| 16.7 | .23 | 19.2 | .51 | 21.9 | 1.34 | 24.4 | 2.15 |
| 16.8 | .20 | 19.3 | .54 | | | 24.5 | 2.19 |
| 16.9 | .17 | 19.4 | .57 | 22.0 | 1.37 | 24.6 | 2.22 |
| | | 19.5 | .61 | 22.1 | 1.41 | 24.7 | 2.25 |
| 17.0 | .15 | 19.6 | .64 | 22.2 | 1.44 | 24.8 | 2.29 |
| 17.1 | .12 | 19.7 | .67 | 22.3 | 1.47 | 24.9 | 2.32 |
| 17.2 | .09 | 19.8 | .70 | 22.4 | 1.50 | | |
| 17.3 | .06 | 19.9 | .73 | 22.5 | 1.53 | 25.0 | 2.35 |
| 17.4 | .03 | | | 22.6 | 1.56 | 25.1 | 2.38 |
| 17.5 | .00 | 20.0 | .76 | 22.7 | 1.59 | 25.2 | 2.42 |
| | | 20.1 | .79 | | | 25.3 | 2.45 |

¹ Stanek, Zeit. Zuckerind. Böhmen, 35 (1911), p. 187.

The percentage of the dry substance is then obtained from Table XXVII.

TABLE XXVII.—*Dry substance equivalent to temperature corrected immersion refractometer readings (20 grams to 100 cc).*¹

| Refractometer reading. ² | Dry substance. | Refractometer reading. ² | Dry substance. | Refractometer reading. ² | Dry substance. | Refractometer reading. ² | Dry substance. |
|-------------------------------------|----------------|-------------------------------------|----------------|-------------------------------------|----------------|-------------------------------------|----------------|
| ° C. | Per cent. | ° C. | Per cent. | ° C. | Per cent. | ° C. | Per cent. |
| 74.0 | 77.35 | 79.0 | 83.70 | 84.0 | 90.05 | 89.0 | 96.35 |
| 75.0 | 78.60 | 80.0 | 84.95 | 85.0 | 91.30 | 90.0 | 97.60 |
| 76.0 | 79.90 | 81.0 | 86.25 | 86.0 | 92.60 | 91.0 | 98.85 |
| 77.0 | 81.15 | 82.0 | 87.50 | 87.0 | 93.85 | 92.0 | 100.00 |
| 78.0 | 82.40 | 83.0 | 88.75 | 88.0 | 95.10 | | |

¹ Stanek, Zeit. Zuckerind, Böhmen, 35 (1911), p. 187. ² Tenths of readings may be interpolated.

Subtracting the percentage of dry substance from 100 gives the percentage of moisture.

To illustrate the manner of using the tables, 20 grams of sugar made up at 15.5° C. gave a reading of 90.15. The correction for 15.5° C. is 0.58, which subtracted from 90.15 gives 89.57. The dry substance for 89.0 is 96.35 per cent and for 90.0 it is 97.60 per cent, a difference of 1.25 per cent. Fifty-seven hundredths of 1.25 is 0.71, which added to 96.35 gives 97.06, the percentage of dry substance, or a moisture content of 2.94 per cent.

Table XXVIII shows that the results by this method approached very nearly the results of the usual drying method.

TABLE XXVIII—*Moisture content of sugar by drying and by refractometer.*

| Sample No. | Drying. | Refractometer. |
|------------|-----------|----------------|
| | Per cent. | Per cent. |
| 1..... | 1.35 | 1.40 |
| 2..... | .62 | .65 |
| 3..... | 2.32 | 2.40 |
| 4..... | .85 | .90 |
| 5..... | 1.96 | 2.09 |

MAPLE CREAM, HONEY, AND WAX.

Among the numerous products made from maple sap may be mentioned maple cream (or maple butter), maple honey, and maple wax.

Maple cream is produced by boiling the sirup to a density slightly heavier than that for a soft sugar and suddenly cooling the product, stirring all the time with a large spoon or paddle. This beating and cooling tends to produce microscopic crystals of sugar which give the product a creamy appearance and do not separate out on standing if the proper density is maintained. An early run of sirup is not the best for this product, as some inversion of the sucrose is necessary to obtain the best results. This product has been called maple butter in some sections and is frequently prepared by farmers.

Maple honey is the name often given to a light-colored maple sirup which has been boiled to a density slightly heavier than that of sap sirup, or similar to that of strained honey. The sirup could hardly be an early run, but should be one in which there has been some inversion of the sucrose, for otherwise the product will soon crystallize. As this substance has no connection with bees and is never stored in combs, the fitness of its name may be questioned.

Maple wax is prepared by boiling sap sirup to a density nearly equal to that of hard sugar, but without stirring, and then pouring the product over snow or ice to secure an immediate cooling, thereby preventing crystallization of the sugar. This can be made only in small quantities and does not keep its waxy condition for any length of time.

As in the case of maple sugar, chemical examination of these products should be carried on by concentrating them in solution to a sirup with a density of 65, calculating the analytical results so obtained to the moisture-free basis, and determining the original moisture content.

CONCLUSIONS.

ANALYTICAL FIGURES OF PURE MAPLE PRODUCTS.

Moisture.—Maple sirup should have a density equivalent to at least 65 per cent dry substance or, in other words, it should weigh 11 pounds to the gallon. A thinner product does not keep, and a heavier one shows more or less crystallization, depending on the quality of the sap and on manufacturing conditions. Maple sugar with a water content much over 5 per cent is runny and drains easily. In tub sugar, the moisture content may run as high as 10 to 12 per cent, but beyond this the sugar becomes mushy.

Sugars.—Sucrose normally constitutes about 95 per cent of the dry substance of the maple product, and, together with about 3 per cent of reducing sugars, forms the total sugar content. In some samples sucrose constituted about 97.5 per cent of the product. In normal sirup, or sirup in which no acid fermentation has taken place, the sum of the sucrose and the reducing sugars calculated to sucrose by the factor 0.95 will give a figure ranging very close to 97.5 per cent of the dry substance.

Ash.—The total ash is an important figure in the analysis of a maple product. The average percentage in 481 samples of maple sap sirup was found to be 1 per cent, with extremes of 1.68 and 0.68. In the 363 samples of maple sugars, the average was 0.98 per cent, with extremes of 1.70 and 0.76 per cent, all figured to a dry basis. Examining the results on these samples critically, we find that out of the 844 samples 10 have an ash content of 0.77 per cent or lower (Table XXIX).

TABLE XXIX.—*Samples of maple products with a total ash content of 0.77 per cent or less.*

| Serial No. | Total ash. | Insoluble ash. | Winton lead number. | Malic acid value. | Serial No. | Total ash. | Insoluble ash. | Winton lead number. | Malic acid value. |
|------------|------------------|------------------|---------------------|-------------------|------------|------------------|------------------|---------------------|-------------------|
| | <i>Per cent.</i> | <i>Per cent.</i> | | | | <i>Per cent.</i> | <i>Per cent.</i> | | |
| 6680..... | 0.68 | 0.26 | 2.22 | 0.66 | 7743..... | 0.76 | 0.45 | 1.86 | 0.75 |
| 8365..... | .77 | .23 | 1.96 | .61 | (1) | .77 | .22 | 2.04 | .62 |
| 8354..... | .77 | .23 | 2.13 | 1.15 | (1) | .77 | .22 | 2.42 | .61 |
| 8349..... | .77 | .22 | 1.86 | .92 | (2) | .76 | .25 | 1.87 | .62 |
| 8351..... | .76 | .23 | 1.85 | .78 | (2) | .77 | .24 | 1.86 | .60 |

¹ Taken from experimental work on change in color from sap to sugar sirup.

² Taken from experimental work on resugaring.

Thus, in the examination of 844 samples, it is noted that a total ash content of 0.68 per cent has been found in one case only, and 0.76 per cent in three cases only; all other samples give 0.77 per cent or over. In these four cases, all other figures are within those found in normal products, namely, Winton lead number 1.85 or over, insoluble ash 0.23 or over, and malic acid 0.59 or over. It seems then that percentages of ash lower than 0.77 per cent are abnormal figures and do not necessarily indicate a mixture with other sirup, especially cane-sugar sirups.

The insoluble ash analysis is of equal importance with that of the total ash. Among the sap sirups the lowest insoluble ash content was found to be 0.23 per cent, with an average of 0.37 per cent and an extreme of 1.01 per cent. Three samples of sugar sirups had an insoluble ash content below 0.23 per cent, but the average was 0.36 per cent and the extreme 1 per cent, practically the same as in the case of sap sirup. In the experimental work about five additional samples with an insoluble ash content of 0.22 per cent were found. The results on these eight samples appear in Table XXX.

TABLE XXX.—*Samples of maple products with an insoluble ash content below 0.23 per cent.*

| Serial No. | Total ash. | Insoluble ash. | Winton lead number. | Malic acid value. | Serial No. | Total ash. | Insoluble ash. | Winton lead number. | Malic acid value. |
|------------|------------------|------------------|---------------------|-------------------|------------|------------------|------------------|---------------------|-------------------|
| | <i>Per cent.</i> | <i>Per cent.</i> | | | | <i>Per cent.</i> | <i>Per cent.</i> | | |
| 8349..... | 0.77 | 0.22 | 1.86 | 0.92 | (1) | 0.77 | 0.22 | 2.42 | 0.61 |
| 8344..... | .78 | .21 | 1.85 | .59 | (1) | .81 | .22 | 1.96 | .60 |
| 8330..... | .81 | .22 | 2.01 | .77 | (1) | .88 | .22 | 2.20 | .66 |
| (1) | .77 | .22 | 2.04 | .62 | (1) | .85 | .22 | 1.96 | .69 |

¹ Taken from experimental work on change in color from sap to sugar sirup.

All have a total ash content of 0.77 per cent or higher, a Winton lead number of 1.85 or higher, and a malic acid value of 0.59 or higher. With the possible exception of No. 8344, these samples are abnormal in their insoluble ash content but normal in the other figures. Finding only 3 samples out of 844 with an insoluble ash

content lower than 0.23 per cent and with other figures normal, it seems fair to conclude that a pure maple product should have at least 0.23 per cent insoluble ash or, if it has less, that the other figures should be above the minima.

Winton lead number.—Much stress is laid upon the Winton lead number in judging a maple product. Among the 481 sap sirups, the lowest number was 1.76, the next being 1.85, the highest 4.41, and the average 2.70. With the maple sugars, the lowest was 1.85, the highest 4.95, and the average 2.76.

TABLE XXXI.—*Samples of maple products with a Winton lead number of 0.85 or lower.*

| Serial No. | Total ash. | Insoluble ash. | Winton lead number. | Malic acid value. | Serial No. | Total ash. | Insoluble ash. | Winton lead number. | Malic acid value. |
|------------|------------------|------------------|---------------------|-------------------|------------|------------------|------------------|---------------------|-------------------|
| | <i>Per cent.</i> | <i>Per cent.</i> | | | | <i>Per cent.</i> | <i>Per cent.</i> | | |
| 6693..... | 0.97 | 0.26 | 1.76 | 0.31 | 6635..... | 0.91 | 0.27 | 1.85 | 1.68 |
| 6613..... | .88 | .23 | 1.85 | .79 | 6827..... | .77 | .23 | 1.85 | .72 |
| 6577..... | .80 | .23 | 1.85 | .73 | 6891..... | .83 | .35 | 1.85 | .80 |
| 6768..... | .78 | .24 | 1.85 | .80 | 8344..... | .78 | .21 | 1.85 | .59 |

The sample with 1.76 was abnormal in this respect, being the only one out of 844, but the other determinations are above the selected minima. The total ash in each case is 0.77 per cent or over, and in only one case, No. 8344, is the insoluble ash content below 0.23 per cent. In two cases, however, the malic acid value is below 0.60. Here one sample only out of 844 has a lead number below 1.85, and as this sample is normal in ash and insoluble ash, 1.85 should be considered the lower limit for such a figure.

Ross lead number.—This determination was not made in the case of the sap sirups. It was made in 282 of the 283 sugar sirups from the United States and in 26 of the 80 sugar sirups from Canada. Of these 308 samples, only 6 cases were noted in which values of 2.35 or lower were obtained. The lowest value found was 2.20, the highest 5.90, and the average 3.50.

TABLE XXXII.—*Samples of maple sugars with a Ross lead number of 2.35 or lower.*

| Serial No. | Total ash. | Insoluble ash. | Ross lead number. | Malic acid value. | Serial No. | Total ash. | Insoluble ash. | Ross lead number. | Malic acid value. |
|------------|------------------|------------------|-------------------|-------------------|------------|------------------|------------------|-------------------|-------------------|
| | <i>Per cent.</i> | <i>Per cent.</i> | | | | <i>Per cent.</i> | <i>Per cent.</i> | | |
| 8344..... | 0.78 | 0.21 | 2.20 | 0.59 | 7560..... | 0.78 | 0.27 | 2.31 | 0.67 |
| 6373..... | .78 | .36 | 2.22 | .74 | 7512..... | .78 | .23 | 2.32 | .62 |
| 6374..... | .82 | .39 | 2.25 | .83 | 6617..... | .78 | .34 | 2.35 | .62 |

Of these six samples it is noted that, with the exception of 8344, determinations of other values do not fall below 0.77 total ash, 0.23 insoluble ash, and 0.60 malic acid. As, with the exception of 8344, these samples are not found in Table XXXII, it is apparent that the Winton lead value also was not below 1.85. Even in the case of

8344, the one apparently abnormal sample among some 844 samples, it is noted that all of the values do not fall below the minima just given. Applying the Ross lead number determination, which has been advanced for application in particular to mixtures of maple and cane sugar sirup, to pure maple products, it would appear that 2.25 should be considered the lower limit for this value.

Malic acid value.—Some food chemists lay great stress upon this determination, the minimum value for which in sap sirups was found to be 0.21, with an average of 1.01 and a maximum of 1.82. Only 6 samples out of the 481 had a value below 0.60. In the sugar sirups, the lowest value was 0.51, the next lowest 0.59, and all the rest were above 0.60, the average being 0.93 and the extreme 1.72. Table XXXIII shows the analytical figures of the samples having a malic acid value lower than 0.60.

TABLE XXXIII.—*Samples of maple products with a malic acid value below 0.60.*

| Serial No. | Total ash. | Insoluble ash. | Winton lead number. | Malic acid value. | Serial No. | Total ash. | Insoluble ash. | Winton lead number. | Malic acid value. |
|------------|------------------|------------------|---------------------|-------------------|------------|------------------|------------------|---------------------|-------------------|
| | <i>Per cent.</i> | <i>Per cent.</i> | | | | <i>Per cent.</i> | <i>Per cent.</i> | | |
| 6693..... | 0.97 | 0.26 | 1.76 | 0.31 | 6926..... | 0.87 | 0.35 | 1.98 | 0.52 |
| 6692..... | 1.01 | .24 | 2.36 | .44 | 6915..... | .84 | .23 | 2.65 | .21 |
| 6773..... | .77 | .26 | 2.63 | .58 | 8344..... | .78 | .21 | 1.85 | .59 |
| 6918..... | .89 | .26 | 1.86 | .54 | 8379..... | .88 | .29 | 2.28 | .51 |

All these samples have a total ash content of 0.77 per cent or higher and with one exception an insoluble ash content of over 0.22. The lead number in each case, with one exception, is 1.85 or higher. It then seems proper to consider that a pure product must have a value of 0.60 per cent. Abnormal products may have a value below this, but they are not abnormal at the same time in ash or insoluble ash.

Considering the subject as a whole, a pure maple product does not yield figures below the minima set. In one or two of the determinations it might give a figure below the minimum for such a determination. If pure, however, it shows in the other determinations figures which exceed the minima.

The minima set are: Total ash 0.77 per cent, calculated to dry basis; insoluble ash 0.23 per cent, calculated to dry basis; Winton lead number 1.85, calculated to dry basis; malic acid value 0.60, calculated to dry basis.

These apply also to the samples of maple sirups which Jones ¹ reports as having lower minima. Of the 34 samples reported by him as being low in some particular, 6 show all figures below the minima just stated. The remainder are above in some of the determinations.

¹Vt. Agr. Exp. Sta. Bul. 167, p. 464.

TABLE XXXIV.—*Analytical figures of six samples showing low results.*¹

[Calculated to dry basis.]

| Sample No. | Total ash. | Insoluble ash. | Malic acid value. | Water in original sample. |
|------------|------------------|------------------|-------------------|---------------------------|
| | <i>Per cent.</i> | <i>Per cent.</i> | | <i>Per cent.</i> |
| 106..... | 0.69 | 0.22 | 0.59 | 30.48 |
| 119..... | .64 | .22 | .59 | 28.75 |
| 114..... | .71 | .22 | .56 | 30.69 |
| 107..... | .71 | .21 | .58 | 27.90 |
| 112..... | .71 | .21 | .44 | 31.34 |
| 108..... | .65 | .20 | .49 | 29.64 |

¹ Jones, Vt. Agr. Exp. Sta. Bul. 167, p. 464.

The first three samples in Table XXXIV show an insoluble ash content only 0.01 per cent below the minimum set. Of these three, two have a malic acid value 0.01 per cent below the minimum; the other, one that is 0.03 below. This deviation is almost too slight to consider. Although low in malic acid values, the insoluble and total ash figures of the three remaining samples, with the exception of No. 108, approach very closely the minima set. A comparison with the data in Table V (page 6) indicates that, with the exception of the malic acid value, the analytical figures of sample 108 are increased if water is added and the concentration not carried too far.

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THE FOOD VALUE AND USES OF POULTRY.¹

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INTRODUCTION.

Among the animal products used for human food few have been longer or more widely known than poultry. The kinds of birds included under the term have naturally varied with time and place. Formerly not only game birds but also small animals, such as rabbits and squirrels, were spoken of as poultry, apparently because they were all sold by one dealer, known as a "poulterer," and because they played very similar parts in the bill of fare. At present the word is commonly and correctly used in a more limited sense to describe birds bred especially for their eggs, flesh, or feathers. This excludes wild birds, even when they are used for food, and also such birds as peacocks and swans when they are bred simply for ornament. On the other hand, when such birds as pheasants or quail are domesticated for table use, or when peafowls and swans are utilized as food, they are properly classed as poultry.

At present the most important kinds of poultry in the United States are chickens, turkeys, guinea fowls, pigeons or squabs, ducks, and geese, while peafowls, pheasants, quail, and swans occasionally

¹ Prepared under the direction of C. F. Langworthy, Chief, Office of Home Economics.

NOTE.—This bulletin brings together general information and summarizes the results of experiments data regarding the food value of poultry and its uses in the home, together with information on the handling and care of poultry and similar subjects which will prove of assistance in choosing poultry for the home table. It is believed that the material will prove useful especially to housekeepers, extension workers, teachers, and students of home economics.

come under the same head. Of these, chickens, turkeys, guinea fowls, peafowls, pheasants, and quail belong to the order of Gallinaceæ; pigeons to Columbidae; and ducks, geese, and swans to Natatores.

Some idea of the extent of the poultry industry in the United States can be obtained from the figures of the last census. Of all the farms giving returns in 1909, 87.8 per cent reported poultry of some kind. The total number of chickens reported was 280,345,133; turkeys, 3,688,708; guinea fowls, 1,765,031; pigeons, 2,730,994; ducks, 2,906,525; and geese, 4,431,980. Although many chickens are kept for their eggs rather than their flesh, nearly all of them are finally eaten, and almost all of the other kinds are bred primarily for the table. Allowing for increased production since the figures quoted were gathered, it is safe to say that 300,000,000 chickens and other poultry, or about three birds to a person, are now consumed in this country every year.

Since poultry is such a general and important branch of agriculture, it is not surprising that a great deal of experimenting has been done and many publications issued regarding the best methods of production and marketing. Comparatively little has been written, however, from the point of view of the consumer, and many, especially those who depend upon markets, could select to better advantage if they had more definite knowledge of the varieties, the ways in which they are bred and marketed, the marks by which their quality is to be judged, their relative value as food, and the ways in which they may be economically used in the ordinary diet. This bulletin, therefore, discusses not only the nutritive value and place of poultry in the diet, but also gives brief descriptions of the varieties and the common methods of producing and marketing, with special reference to the effect of these factors on the table quality and food value of the birds.

KINDS OF POULTRY.

CHICKENS.

Chickens, which are also known as barnyard fowl, have been bred for so long and in so many parts of the world that there is some uncertainty as to where they were first domesticated. It is probable, however, that they are descendants of a wild jungle fowl of Asia.

A good table bird should have a large proportion of flesh to the size of its bones and a large, full breast, on which is found the delicate white meat. Long, thin legs and wings are undesirable, as they contain much bone and little meat. Birds with light-colored feathers are, perhaps, easier than dark ones to make attractive for the market, which demands a skin free from visible pin feathers. Some markets prefer light-skinned and others dark-skinned varieties, though there is no evidence that the color of the skin has any relation to the quality of the birds.

American poultry experts designate as "meat" or "table" breeds the Asiatic class, which includes Light and Dark Brahmas; Buff, Partridge, White, and Black Cochins; and Black and White Langshans. Almost any of the heavy breeds can, however, be made into good table birds if given proper feeding and care.

Ordinarily, the poultry raiser depends on eggs as well as on table birds for his profit, and selects free-laying, well-shaped, hardy varieties, relying on care and feeding to develop the quality and flavor of the flesh. Plymouth Rocks, Wyandottes, Rhode Island Reds, and Orpingtons are probably the most satisfactory of the common breeds used in this country for "general purpose" birds.

Hens lay most abundantly in the early spring and summer, and hence the best season for "spring" chickens and broilers—i. e., chickens from 2 to 6 months old—is from May to September or October. Fowls or hens are, of course, to be had at all times of year, but they are most frequently sent to market in the winter months, when they are laying poorly. The retail market terms for poultry, as for other commodities, vary somewhat with the locality, but, according to well-established commercial usage in the United States, "broilers" is the technical term for the youngest chickens; then come "frying chickens;" then "roasting chickens;" and finally, "hens" or "fowls."

The flesh of the mature cock is usually too tough and highly flavored and requires too much care in cookery to be satisfactory, so caponizing of the young males is often resorted to. Capons rightly fed and handled are considered exceptionally fine for table use. Their flesh has the tenderness of the pullet, with a much better flavor. Moreover, the tender parts of the body develop more than in ordinary chickens, giving a larger proportion of white meat. They are usually higher in price than other forms of chicken, but because their tender flesh is better distributed over the carcass they may be carved and served more economically than chickens of equal weight, and thus be worth a higher price than ordinary chickens, irrespective of their texture and flavor.

Poulards, as the spayed females are called, are seldom found in American markets, though they are often marketed and are highly esteemed in Europe.

TURKEYS.

The name of these birds is rather misleading and does not suggest that they were originally native in America. They were, nevertheless, introduced into Europe from this continent soon after its discovery. The confusion may have been due to the fact that at that time Turkey was vaguely supposed to be the source of all sorts of strange importations; and these new birds were called "Turkey fowl" in the same loose way that maize was called "Turkey corn." The French name

dinde is a corruption of *poule d'Inde* or "hen of India," and suggests that confusion of the East and West Indies may have added to the general misunderstanding. Although they speedily became popular in Europe and are now used there to a considerable extent, they are not so common there as in the United States, where they rank next to chickens in importance.

Turkey flesh resembles that of chicken; it is sometimes described as drier and not so full of flavor, but proper care and feeding lessen these disadvantages. The proportion of meat to bone is larger in turkeys than in chickens, and the fact that their flesh is found in larger masses sometimes makes it possible to serve it to better advantage, especially in the form of "left overs;" hence, pound for pound, turkey is probably utilized more economically than chicken.

There is little demand for young turkey chicks, which are very scrawny and do not bear shipping well. However, in July and August growers near fashionable summer resorts can sometimes sell "broilers" weighing from 1½ to 4 pounds each at rather fancy prices. The general market rarely sees fresh turkeys before September, and the season can hardly be said to begin before the last of October. Many of the birds are fattened to a very large size (25 to 30 pounds) for the Thanksgiving and Christmas trade, but from January until the season for fresh turkeys ends, in late February or March, medium-sized birds are most abundant and are more suitable for ordinary family use. The bulk of our turkey supply now comes from the South, Middle West, and Southwest, but up to January native turkeys, often of excellent quality, are found in Eastern markets. Practically all the turkeys marketed through the spring and summer months are cold-storage birds from the great poultry-raising sections.

GUINEA FOWLS.

The name of these birds rightly indicates the place of their origin, but since they were first found in western Africa by European explorers they have been carried to many parts of the world. They are more generally bred in Europe than in the United States. In the Southern States they are often kept along with the other poultry, and recipes in southern cookery books suggest that the birds are commonly used for food in that part of the country, but it is only within recent years that guinea fowls have been seen in any quantity in northern markets.

Young guinea fowls are sometimes said to resemble partridge in flavor, and older birds, pheasants. The flesh on the breast is slightly darker than in chicken and has a more gamey flavor. In fact, it is this gamey quality which gives them their distinctive value in elaborate menus or among epicures, and to increase it the birds are allowed to hang until just before they begin to "turn." For ordinary

family meals, however, where they are used in the place of chicken or turkey, the fresh flavor is usually preferred.

Young birds are ready for the market in the early autumn, and older birds are to be obtained throughout the winter. A quick method of cooking, such as broiling, develops the flavor of guinea fowl better than such slow ones as boiling or stewing, and hence young, tender-fleshed birds, which can be quickly cooked, are preferable to older ones.

PIGEONS AND SQUABS.

The varieties of pigeons used for food have been developed from the wild blue rock dove but are considerably larger than their wild ancestors. Even so, the breast is the only part of the body on which the flesh occurs in masses large enough to be used to advantage. The breast muscles, which are slightly lighter in color than the rest, are tender before the birds begin to fly, but rapidly toughen with use until in the mature birds they require long, slow cooking to make them edible. Hence, the young, called squabs, are much superior for table use. They are best when about 4 weeks old, that is, after they have begun to grow plump but before they are ready to leave the nest. They are most plentiful in midsummer, but when artificial mating and breeding are practiced they can be obtained the year round, very fine ones often appearing in midwinter. A publication of this department¹ treats of squab raising for market. There is a great demand for squabs by hotels, restaurants, private hospitals, etc., but their cost is usually too high for them to be used frequently in the ordinary family. The older birds are so seldom eaten in the United States that they are almost a negligible quantity in poultry markets and sell for very low prices. In Europe they are much more commonly used, pigeon pie and potted pigeon being forms in which they are considered especially palatable.

DUCKS.

Most of the domesticated breeds of ducks have been derived from the wild mallard. Duck breeding has long been practiced in the Old World, where both meat and eggs are in common use, but until recently they were raised in this country only incidentally by farmers who happened to have access to pond or stream. Of late years, however, the duck-raising industry has been greatly developed, with the result that the birds are much improved in size and quality, and are more commonly eaten than formerly. The egg-laying strains are also attracting attention.

Duck flesh is dark throughout and has a distinctive flavor, generally considered palatable. There is a relatively small proportion of

¹ U. S. Dept. Agr., Farmers' Bul. 684 (1915).

flesh to bone, and the meat occurs in such thin, small masses that only four good table portions can be obtained from a medium-sized bird. Specially fattened ducks carve to better advantage, besides having more tender and delicately flavored flesh.

Young ducks, usually called ducklings, begin to reach the market in May and may be obtained until January. "Green ducks" is a trade name for those appearing in the spring and early summer. Full-grown birds can be obtained at any season but are usually best in winter.

GEESE.

Geese have been used as table birds at least since the days of ancient Egypt. They are common all over the world, but perhaps are most generally raised for market in Germany, where their flesh is prepared in many forms, ranging from plain roast goose to smoked Pomeranian goose breast and "pickled goose" (pökelgans), which is goose flesh treated as we treat soured pork. Goose fat, carefully rendered and preserved, is also much used in Germany. It is eaten on bread in place of butter, and is considered excellent for the preparation of many dishes. Like chicken fat, it is frequently used as a culinary fat by orthodox Jews everywhere. Such uses of poultry fat and other fats have formed a part of the study of fat and its place in the diet, carried on by the Office of Home Economics.¹

Goose flesh is dark in color and has a pronounced flavor, which seems, in part at least, to be due to the fat which permeates it. Special fattening often increases the market value, and very fat "stall-fed" geese are to be found in large poultry markets. In the studies just referred to such a specially-fattened goose was found to weigh 27 pounds, of which nearly 15 pounds was fat, most of it in a thick layer under the skin.

Even more excessive feeding of geese is practiced in certain parts of Europe, notably around Strasburg, Germany, and Toulouse, France, in order to produce fatty infiltration of the birds' livers. These livers, which frequently weigh 3 pounds or even more, are cooked and seasoned according to special and often carefully guarded recipes and sold in the form of potted paste, ordinarily known by the French name of *pâté de foie gras* (patty of fat liver). The paste has a distinctive flavor much prized by epicures and is used for relishes, sandwiches, and similar preparations, but is too expensive for common use.

For table purposes half-grown or "green" geese are considered most desirable, and may be obtained from May to early winter. Full-grown birds can usually be procured at any season. Geese live to a great age, but after they are 3 years old the flesh toughens and loses its agreeable flavor too much to be good eating.

¹ U. S. Dept. Agr. Bul. 310 (1915).

BIRDS LESS COMMONLY USED AS POULTRY.

There are several kinds of birds which are not bred primarily for their eggs or flesh, but which are, nevertheless, used occasionally for the table, and so should not be entirely overlooked in a description of poultry. The most important of these are peafowl, swan, pheasant, partridge, and quail.

Peafowls were introduced into the Western World from Asia. In classic and medieval times they were considered very delicate eating, the cock, served whole and garnished with his own gorgeous plumage, making the principal dish at many feasts. Peafowls are rare in American markets, though they can usually be obtained on request from a large dealer. In places where they are bred it is sometimes economical and convenient to use surplus birds for the table. There is a large proportion of flesh to bone. Opinions differ regarding the flavor—some consider it dry and tasteless and others think it as delicate as that of pheasants—but all agree that while the young birds, particularly the hen, may offer a pleasing variety in the menu, a mature peacock is not worth eating.

Pheasants have always been considered a delicacy, and now are especially valued for the variety they give to the bill of fare. Their flesh is tender, but has little distinctive taste until it has been kept for some time. The hens are preferred to cocks for table purposes. Most of those seen in American markets have been sent from England or from Russia in cold storage, although the number reared in this country is constantly increasing.

Aside from pheasants, quail and partridge are the principal game birds bred for the table in the United States. There is considerable confusion as to what birds are referred to under these names. The European quail is not found wild in the United States, but several native birds are called quail in different localities, among them the bobwhite and the California quail. Similarly, the word "partridge" may refer to the ruffed grouse, the bobwhite, or the Hungarian partridge (also known as gray partridge), which is being introduced in many game preserves and public reservations. Such birds are bred in captivity for the table to a limited extent, but they have only recently become common in our markets. For a long time to come such domesticated birds will probably be too expensive for common use, though they are sometimes useful to supply variety on special occasions.

Swans were formerly much more commonly used as table birds than at present. Occasionally, when a few are kept among a flock of geese, the young, called cygnets, are killed for eating. Some describe their flavor as delicious, but others consider it too rank.

FACTORS WHICH INFLUENCE TABLE QUALITY.

Desirable quality in the flesh of poultry intended for table use depends on the flavor of the flesh; on its texture, by which is meant the structure of the individual fibers of the muscular tissue and the amount of fat found in tiny particles between them; on the amount of flesh in proportion to the total weight of the bird; and on the distribution of both the flesh and the larger masses of fat over the carcass. These factors in turn depend on several conditions. Besides the general differences between various kinds and breeds of birds, there are differences among birds of the same stock, due to sex, age, exercise, feeding, and methods of handling and marketing, though the natural effect of sex and age is frequently offset by special care and feeding. There is more information available regarding the effect of most of these factors on chickens than on other poultry, but the general principles are probably the same with all.

The effect of sex on table quality is too well known to need long discussion. Other things being equal, the flesh of females is, as a rule, milder in flavor and more tender in texture than that of males. Caponizing makes the flavor of cocks more delicate, tends to produce finer and less tough muscle fibers, and increases the size of the masses of meat, especially in the breast.

Age influences the quality of the flesh in several respects. It tends to increase flavor, at first advantageously, but later usually disadvantageously. Most very young birds have too mild a flavor to be satisfactory. Many persons, for example, consider that the flavor of young chickens such as broilers is not sufficiently developed, and think that the increased richness of taste in birds a year or so old more than compensates for the slight loss of tenderness. On the other hand, the delicacy of flavor is usually lost in decidedly old birds. As the bird grows older, the proportion of flesh to bone usually increases, at least up to the period of full maturity. Often the large masses of flesh found on such birds can be utilized more satisfactorily than the smaller ones found on young and "scrawny" ones.

Exercise affects the flavor and texture of poultry flesh, as it does of any kind of meat. It increases the amount of the protein compounds, known as extractives, on which the specific flavor depends, and it toughens the individual fibers of the flesh and the connective tissue. It further influences both flavor and texture by lessening the amount of fat present, a matter which will be discussed at length in connection with feeding. Exercise may also affect the distribution of flesh on the carcass, increasing especially the naturally strong, tough muscles rather than the less-used, tender ones. In some birds, notably in chickens, the exercise can be more closely controlled than in others, for example, turkeys and guinea fowls, which are put out of condition by long confinement. Almost any poultry, however,

can be safely penned for a few days previous to killing. Regulating exercise is usually closely associated with special feeding. In the special fattening of geese for goose-liver paste (see p. 6), for example, keeping the birds absolutely quiet, sometimes in darkened pens so small that they can not move their wings, is considered as essential as the forced feeding which accompanies it.

The difference between the flesh of a plump chicken and of a lean one of similar kind and age is due principally to the fat present. This fat appears not only in solid masses around the muscles, but also in tiny particles between the fibers of the muscle itself, and these tiny particles make the flavor richer and the texture less close and firm. The skill of the fattener, from the consumer's standpoint, lies not only in producing the desirable amounts of fat at the least expense for food and care, but also in getting the fat well distributed through the flesh rather than merely in masses within the carcass or under the skin. Such large masses have little value for table purposes and unless they are carefully saved and used for cooking they are practically wasted. On the other hand, when the amount of flesh is increased by the fat which occurs between the fibers, the proportion of edible material is increased and the larger masses of meat make better portions in serving.

Besides improving the flavor of the flesh by increasing the fat present, special feed may give specific flavor. Chickens fattened on a mash of grain and milk acquire a delicate flavor, while the "wild" flavor of guinea fowls that find their own food is probably due to the fact that they get a variety of food as they range. The rather rank taste of many water birds has long been believed to be due to the accumulation in their flesh of extractives occurring in the water bugs, fish, and other animal substances which they eat. This theory has been confirmed by recent German work with the European coot, the flesh of which has such a strong flavor and odor that it is usually considered inedible. It was found that these disagreeable qualities are due to monomethylamin, a substance characteristic of the food supply of the birds and similar to one found in decaying meat. It appeared in the skin more than in the flesh, and by removing the former before cooking the disagreeable qualities were largely removed. Special feeding often imparts a very desirable flavor. For instance, canvasback ducks are considered at their best when they have fed on the wild celery characteristic of their favorite feeding ground, and celery and chestnuts are sometimes used to give turkey flesh a special flavor. On the other hand, birds intended for the table should not be allowed to eat onions or wild garlic habitually, because the sulphur compounds in these plants pass over into the flesh and give it a taste which most persons consider undesirable.

The color of poultry flesh, or at least of chicken flesh, may be influenced by the feed. Certain methods of feeding, for example, are based on the fact that milk tends to bleach or whiten the flesh. This matter of color bears little relation to real table quality or nutritive value, and would not need attention except that some markets sometimes demand white and others yellow flesh. These differences are probably the result of old local customs and are fast disappearing now that local-grown poultry is rarely the sole source of supply.

HANDLING AND DRESSING POULTRY.

The way birds are treated from the time the producer considers them ready to be disposed of until they are cooked has almost as much influence on their table quality as their earlier care and feeding. Success in this later stage depends on controlling the changes which take place in the flesh after the birds are killed.

Different methods prevail at different times and places, but however the poultry is handled, cleanliness should be insisted upon everywhere, for both table quality and healthfulness depend upon it in large measure. Dirty pens and runs lead to disease while the birds are alive. After they have been killed cleanliness is equally important, for unless rooms, tables, tools, water, hands—in short, all the articles which come in contact with the birds—are kept in good condition, the flesh is likely to become infected with microorganisms which cause decay and so injure its appearance and flavor. From the point of view of the consumer, dirt in connection with food which is to be cooked is perhaps less dangerous than with something to be eaten raw, but it is nevertheless disagreeable. Moreover, dirt is rightly considered a sign of poor quality in any food material, and it is only just that poultry which shows the marks of careless handling should bring a lower price than clean, attractive-looking birds. By insisting on cleanliness in the poultry and in the markets, the public can help more than is sometimes realized in improving commercial methods, and dealers who try to keep a high standard feel encouraged when their patrons show an intelligent appreciation of their efforts.

MARKETING POULTRY ALIVE.

In the North and West poultry is almost always marketed after killing, but in the South the old custom of marketing birds alive is still common. Birds sent to market alive should be humanely treated. Too close confinement, lack of water, etc., are needless cruelties and injure the appearance and quality of the birds for the table. The purchaser of live poultry often feeds it carefully for a short time to bring it into good condition.

KILLING, PLUCKING, AND COOLING.

According to recommendations made by the Department of Agriculture,¹ it is well to make the bird fast for 12 hours or more before it is killed in order that its crop may be empty and the other organs as free as possible of fecal substances. One of the most satisfactory and humane ways to kill a bird is to hang it head downward and cut the main veins in the neck at the base of the skull, so that quick bleeding is assured. Just as soon as the veins are cut the brain should be pierced with a sharp, stiff, slender knife, to kill the bird and cause the feathers to loosen. If the proper areas in the brain are destroyed by the knife thrust, the feathers may be plucked easily and without tearing the skin. A common way of loosening them is to plunge the carcass into water heated nearly to the boiling point, but this destroys the natural appearance of the skin and also increases the chances of decomposition.

Unless a bird is to be cooked at once it should be put in a cool place where it will lose its animal heat rapidly. Sometimes freshly plucked birds are put into cold water for a short time, with the double purpose of cooling them and making them look plumper. However, such soaking injures the keeping qualities, and if the birds are kept in water until they swell beyond their natural size and weight the practice is fraudulent as well as injurious. A still more objectionable way of plumping birds is by blowing them out. This is bad enough when a bellows is used, but when, as is sometimes the case, the dresser blows directly from his mouth, it is disgusting and dangerous.

DRAWN AND UNDRAWN POULTRY.

One of the much-debated questions among poultry dealers and consumers is whether or not birds keep better when marketed drawn (i. e., with the internal organs removed) or undrawn. Practice varies in different localities. Opening the body and removing the viscera undoubtedly exposes the internal surface to the air, which always contains microorganisms, and thus may hasten decomposition; but, on the other hand, it must be remembered that the viscera decompose more rapidly than other parts of the body, and if left in it may taint or infect the rest of the bird. It is sometimes argued that the contents of the intestines of undrawn poultry may injure the flesh, because dissolved bodies of undesirable flavor can pass through the intestinal walls into the surrounding tissue, but this danger is largely avoided if the bird is starved for a day before killing.

In elaborate experiments with drawn, partially drawn, and undrawn poultry, conducted by the Bureau of Chemistry of this department,² it was found that undrawn birds spoil least quickly, and

¹ U. S. Dept. Agr., Bur. Chem. Circ. 61 (1915), rev.

² U. S. Dept. Agr., Bur. Chem. Circ. 70 (1911).

partially drawn ones less quickly than the fully drawn ones from which not only the viscera but also the heads and feet have been removed.

For household use it may be safe to let the local farmer or the marketman draw the birds just before they are delivered, providing they are to be cooked within a few hours, but otherwise it is probably best to draw them at home. In no case should the interior of the bird be washed until just before cooking, for the moisture which would necessarily remain would be favorable to the growth of injurious microorganisms to the meat and would be more dangerous than anything the washing might remove. Another disadvantage of buying birds drawn is that it is more difficult to judge the age and freshness of the bird when the head, feet, and intestines have been removed. (See p. 16.)

The head and feet, usually considered as waste in this country, are commonly used in Europe for gravy or soup making and are occasionally sold for this purpose in the United States. The masses of fat such as are found around the entrails are sufficiently valuable for culinary purposes to be sold in some markets for as much as 50 cents a pound at retail. The giblets or edible entrails (gizzard, heart, liver, and sometimes lungs) are often cooked and used in stuffing or gravy. Chicken livers are considered a great delicacy by many and bring high prices when sold separately. If any of these parts are removed and kept by the marketman, allowance ought to be made in the price. The inedible entrails, on the other hand, have no value to the housekeeper and should be disposed of at once, as they spoil quickly and taint whatever they come in contact with.

CHANGES IN POULTRY FLESH.

After the animal heat leaves the body, a condition known as "rigor mortis" sets in, which stiffens the flesh and tendons. After some hours, however, this stiffness begins to pass off, probably as the result of the growth of microorganisms or the action of natural ferments in the flesh. Because of this, poultry should either be cooked within a few hours after killing or else kept for a day or two. Along with this softening of the flesh and tendons, other changes also take place which, when they have become more apparent, are called decomposition or putrefaction. In their later stages they are accompanied by a characteristic odor and a disagreeable, acid taste, and sometimes by a change of color. The younger the bird and the softer and moister the flesh the more rapidly does this decomposition set in. The microorganisms which produce these undesirable chemical changes in flesh grow more quickly at a moderately high temperature than at a low one, and in a damp place than in a dry one, and the meat must, therefore, be stored in a cool, dry place. Clean-

liness in surroundings, in handling, and in everything else concerned is essential, for dirt introduces microorganisms which cause decay. Ordinarily poultry will remain sweet for a week or more at a temperature of 50° F., but if it is to be kept longer it must be stored in a dry place at a temperature no higher than 34° F., which, except in winter weather, means in artificial cold storage.

COLD-STORAGE POULTRY.

In former times every family in the country either raised its own poultry or obtained it from some neighbor, while town and city dwellers bought theirs direct from a farmer or from a retail market which received it direct from the farm. Such local supplies can still be obtained in many rural districts and small cities, and to a limited extent in large cities; and provided that the grower cares for the birds properly, this direct method of marketing probably brings the birds to the household in the freshest possible condition. For a long time, however, the farms within easy driving distance of the larger cities have not been able to supply all the poultry needed and birds have been shipped in from long distances. To what extent our markets are dependent upon poultry from a long distance may be seen from the last census, which shows that over half of the poultry used in the United States is produced in only 10 States, most of them in the central groups. Of course, this change in the poultry supply could not have taken place without a corresponding development of refrigerating machinery and methods of transportation, which has made it feasible to ship fresh birds for hundreds of miles and to hold them for market in good condition for a length of time which would have been impossible not many years ago.

The whole cold-storage business has developed so rapidly during the last 20 years that the public still has rather vague ideas regarding many features of it. As far as poultry is concerned, chickens make up by far the largest part of the total amount handled, but large quantities of turkeys and a limited number of ducks, geese, and other birds are also stored. The methods of treating the different varieties are fundamentally the same.

It is hardly surprising that there is a good deal of confusion as to exactly what is meant by cold-storage poultry, for very few definitions or standards have been set up to describe it in different States, and those that have been adopted are often conflicting. It has been suggested that the term "cold-storage poultry" be used to describe all poultry which has been kept for more than 30 days at a temperature below 45° F. If such a definition were legally adopted, the practical effect would be that no birds which had been kept for more than a month could be sold as fresh. To a person accustomed to think of fresh poultry as that which has been kept for a few days

only, even 30 days might seem a long time. But it should not be forgotten that with the best modern methods of refrigeration poultry several weeks old reaches the consumer in better condition than some only a few days old which has not been properly cared for.

Until some definite standard for fresh and cold-storage poultry is generally adopted it will be easier for the ordinary retail buyer to understand what is being offered if he realizes that there are two general methods of marketing birds from cold-storage warehouses. One deals with those which are expected to reach the consumer within a few weeks and which are known to the trade as fresh poultry, and the other with birds which are to be held in cold-storage warehouses for some time, usually until the fresh supply runs low again, and which are often called frozen poultry.

The so-called "fresh" poultry, from typical large, well-equipped establishments where the birds are bought alive and specially fattened at the shipping plant, is killed by cutting the main veins of the neck and pricking the brain, is hung head downward to drain, and is plucked without scalding. It is then hung on special racks in a chill room, where it is kept for at least 24 hours, usually at a temperature between 35° and 30° F. For long journeys in hot weather the birds are sometime frozen stiff at a much lower temperature. The next step in the process is packing, which should be done at about the same temperature as the chilling. The birds are graded according to size and quality and are usually packed in uniform boxes with not more than 12 birds to a box. Birds of the best quality are sometimes separately wrapped in parchment paper and packed in cartons holding only a pair. Such separate packing not only prevents the birds from losing shape and from rubbing against each other, but also keeps the flesh from becoming too dry.

Frequent changes of temperature seem to increase the rate at which the undesirable microorganisms develop in the flesh of poultry, and hence such variations are avoided as much as may be both in the storehouse and during transit. The special refrigerator cars designed for shipping such produce as poultry, with their insulated walls and their ice bunkers for use when the outside air is warm, make it possible for the 10,000 to 20,000 pounds of poultry which constitute a carload to travel literally from one end of the country to the other without having the temperature vary more than five degrees.

Under the present conditions of marketing, poultry may have to pass through the hands of several dealers—wholesaler, commission man, retailer, etc.—before it reaches the consumer, and it is almost impossible to prevent its becoming more or less warm during the various transfers. In order to reduce such changes as much as possible the stock is kept in cold-storage chambers by each dealer,

and progressive retailers sometimes even use refrigerated show cases. The consumer should insist that the birds be kept in a cold place until they are delivered to him, and should use them as soon as possible after they reach his home.

Sometimes, especially in hot weather, poultry which is to be sold as fresh—that is, within a few weeks of killing—is frozen before it is shipped. As a general rule, however, the term frozen poultry is used to describe that which has been held at a very low temperature (sometimes below 0° F.) until the birds are frozen very hard, and which is then stored at a temperature below freezing for several months—sometimes for many months. Dealers with cold-storage warehouses buy up large quantities of chickens when they are most plentiful, freeze them, and carry them over to be marketed during the next off season.

When poultrymen first began to freeze poultry it was claimed that no changes took place in the flesh while it was held at these low temperatures. Experiments conducted by the Bureau of Chemistry of the United States Department of Agriculture under commercial conditions and with the cooperation of poultry warehousemen¹ have not confirmed this. Chemical and bacteriological changes do take place, though they may be too slight to be noted by sight, smell, or touch, even when the carcass is thawed. These changes depend very largely on the way in which the bird was dressed and handled before the freezing, as well as on the length of time it is held in the frozen condition. Most of the objection to the frozen poultry of the past arose from careless preparation for storage and from the refreezing of thawed poultry by poultry dealers. In the past there was also a tendency, when the market conditions were bad, for dealers to freeze “fresh” stock on the verge of decay, that it might not be a total loss. This practice has injured the entire poultry industry because it substituted an article of poor quality for a good one. With the better understanding of cold storage such occurrences are becoming less and less frequent and frozen poultry is, therefore, improving.

The length of time during which poultry properly prepared for storage can be kept hard frozen without injury to quality is fairly well known. Researches in the Department of Agriculture have shown that such birds may be kept for 9 to 10 months and still be not only wholesome but of good table quality. This makes the season for cold-storage birds coincide with the seasons of natural scarcity and insures a continuous supply, especially of younger birds, such as broilers and tender roasting chickens. The change most likely to be noticed in a bird held for a considerable period in cold storage is a loss of juiciness in the flesh, but it is not always easy to detect the difference

¹ U. S. Dept. Agr., Bur. Chem. Circ. 64 (1911).

between the flavor of fresh and of properly handled stored birds. While frozen poultry will keep in good condition for several days after thawing, the flavor is better if the bird is cooked as soon as possible after the frost is out.

The way in which frozen birds are thawed makes a great difference in the length of time they keep in condition. It used to be customary to thaw them by soaking in cold water, but this has been proved undesirable not only because the water is very likely not to be clean, but also because soaked birds "go off" in quality very rapidly. Soaking in hot water, as is sometimes done in market for a "rush order," is even worse. A much better way is to keep the birds for 24 hours at ordinary ice-box temperature (45° to 50° F.). As has been already stated, the sooner the birds are used after thawing, the better, and whenever possible birds should be bought stiff and thawed at home. This means buying poultry a day before it is needed, but it is the surest way of having it properly thawed. In warm weather it should be put in the refrigerator to thaw, but in cold weather a moderately cool room will do as well. If it is impossible to do the thawing at home, the marketman should not be allowed to do it until a short time before delivery.

Although frozen poultry is hardly to be chosen when fresh birds are in the market, it undoubtedly has the advantage of furnishing chickens, turkeys, and other birds when the natural supply is lacking and thus increasing the variety of the meat list. It also does something toward keeping prices more uniform than they would otherwise be.

MARKS OF GOOD TABLE POULTRY.

FRESHNESS.

In a freshly killed bird the feet feel moist, soft, and limber, and if it was dressed with the head on, the eyes look bright and full. As it becomes stale the eyes shrink and the feet dry and harden; when too stale, i. e., when decomposition is well under way, the body turns dark and greenish or becomes slimy. The flesh should be neither flabby nor stiff, but should give evenly and gently when pressed by the finger. It is very difficult to distinguish between good cold storage and freshly killed poultry.

AGE.

One of the commonest ways of testing the age of dressed poultry is to take the end of the breastbone farthest from the head between thumb and finger and attempt to bend it to one side. In a very young bird, say a "broiler" chicken or a green goose, it will be easily bent, like the cartilage in the human ear; in a bird a year or

so old it will be brittle, and in an old bird, tough and hard to bend or break. Unfortunately there are sometimes tricky dealers who break the end of the breastbone before showing the bird, and thus render the test worthless. If the feet are left on the carcass, they furnish a mark of age. In a young bird they are soft and smooth, becoming hard and rough as the bird grows older. The claws are short and sharp in a young bird, growing longer and blunter with age and use. Spurs generally occur on male chickens. On male broilers and tender roasting chickens they are small; on older, higher-flavored ones they are prominent but flexible; on cocks they are long and attached to the bones of the legs; on capons they seldom develop until the second year of age.

Turkeys up to a year old are said to have black feet, which grow pink up to three years old and then gradually turn gray and dull.

The age of pigeons can sometimes be told by the color of the breast, which becomes more and more purplish as the bird grows older. Red feet are also said to be a sign of age in a pigeon.

In ducks and geese the flexibility of the windpipe is a mark of youth. It can be easily squeezed and moved when the bird is young, but later grows rigid and fixed.

Turkeys, ducks, and geese are often marketed with the wing feathers on, while guinea fowl, pheasants, and other game birds are very commonly sold without any plucking. Capons are frequently marketed with the feathers left on head, hackle, saddle, legs, and wings. When the plumage is naturally handsome it adds much to the attractive appearance of the bird. Since laws for the protection of game birds have become more strict the feathers of some kinds of poultry have come to be valued for millinery and other ornamental purposes. Aside from this, they are of aid to the housekeeper because they give a clue to the age of the bird. If the tips of the quills at the end of the wing are sharply pointed the bird is probably young; the blunter they are, the older the bird.

SEX.

Commonly it takes a trained eye to distinguish sex in dressed birds, but fortunately this is not important save in the case of capons. When caponizing has been properly done the head is small for the size of the body, the comb and wattles are pale and withered, the body plumper, rounder, and larger than in an ordinary fowl, and the spur abortive. If the operation was incomplete, the head will be like that of an ordinary bird and the body less rounded. Such birds, known technically as "slip capons," are much inferior to true capons.

COOKING.

The purpose of cooking poultry is the same as with any other material, namely, to produce chemical and physical changes which improve the flavor and texture and to destroy any microorganisms which may be present. The heat of cooking softens the fibers and connective tissues which form the greater part of poultry flesh, and thus gives the digestive juices a better chance to act upon them. On the other hand, the protein (nitrogenous substance found in the lean of meat) is hardened by the strong heat, much as white of egg, which it resembles in chemical composition, hardens in boiling. Protein thus hardened or coagulated may be somewhat less readily though not less thoroughly digested than slightly cooked or raw protein; for most persons, however, this disadvantage in the cooked meat is more than offset by what custom makes them consider its more attractive taste and appearance. The fats, too, are affected by the heat; being melted out from the flesh to some extent, they make it appear more juicy.

Boiling, stewing, roasting, broiling, and frying are the methods of cooking ordinarily used with poultry, as with other meats.

In boiling and stewing the heat reaches the flesh through the water in which it is placed, and the chief difference between the two lies in the amount of heat applied at one time. The choice to be made between them should depend on whether the flesh only is to be used or also the water in which it is cooked. If the flesh only, the bird should be boiled; that is, plunged into water which is already at or near the boiling point and allowed to stay at that temperature for from 10 to 20 minutes. This exposure to the greater heat will cause the protein near the surface to harden and form a sort of coating which the juices of the interior can not so readily pass. Later the pot should be set in a cooler place and the meat be left in water slightly below the boiling point until the desired changes have taken place in its inner parts. When, on the other hand, the water also is to be used, the bird should be stewed; that is, put into water while it is still below the boiling point and kept there until thoroughly cooked, since at a moderate temperature no impervious coating of coagulated protein will form, and part of the juices, etc., will escape from the meat into the water.

In roasting and broiling poultry the heat reaches the meat through the air instead of through water. The dry heat causes the protein near the surface to harden, thus partially preventing the escape of the juices; it also causes the meat to brown on the surface, and thus produces a new and appetizing flavor. If recourse is had to basting, or pouring the escaped juices over the hot meat, a coating is formed over the surface, which aids in keeping in the remainder of the juices and increases the "browned" flavor. The larger the fowl, the longer the

time required for the interior to become hot. On the other hand, if the bird is small, there is danger of the interior drying out with prolonged heat, and it should be cooked as quickly as possible. Hence the rule that the smaller the bird the hotter the oven and the shorter the period of cooking should be.

When the layer of meat over the bones is very thin, as in young chicks or squabs, broiling is preferable to roasting. Here very intense heat is applied to one side of the meat until the surface is coated over with coagulated protein, then the other side, and so on alternately until the interior is cooked.

In frying, whether in a pan or in deep fat, the heat reaches the meat through hot fat instead of water or air. Like broiling, this process seems appropriate only for thin pieces of meat. The hot fat on the surface forms a coating which keeps the juices in; or, when the meat is dipped in batter before frying, the latter forms the coating and adds its own browned flavor to the flavor of the meat. The fat should be very hot when the meat is put in, else it may soak into the flesh and spoil the flavor.

Cookbooks and bills of fare suggest almost endless ways of cooking poultry, but it will be found that they all correspond in principle to the methods described and that the differences between them usually lie in the way in which the dishes are flavored by dressing or sauce or in the way they are treated after their first cooking. Chicken pie, for example, is stewed or boiled chicken plus the crust and a little sauce, and chicken croquettes are rather finely divided boiled or roasted chicken plus the seasoning, etc., with which the meat is mixed and the crumbs in which it is rolled before frying. The nutritive value of these dishes depends, of course, on all the materials which go into them.

POTTED AND CANNED POULTRY.

In commercial establishments the meat for these goods is prepared in essentially the same way as if it were to be used immediately, and then is treated much as any other canned meat product, the object being to sterilize the can contents and exclude the air, with the microorganisms always present in it. If sterilization is not complete, there is, of course, danger of decomposition and its attendant evils. Another possible but slight danger is that of poisoning from improper tin and solder, but this is not so great with meats as with fruits and vegetables, in which the acids aid in the formation of dangerous substances. There is no reason why canned poultry, properly put up, should not be just as healthful as fresh, for which it is often a most convenient substitute.

Within the last few years it has become fairly common for housekeepers, especially in rural regions where it is difficult to obtain

butcher's meat, to can meat for home use, just as they do fruits and vegetables. Although beef and pork are most used for this purpose, poultry is also put up with considerable success. The birds are first cooked as if they were to be used at once—sometimes boiled or stewed, sometimes fried or broiled—and are packed in jars or cans much as fruit is. Then they are sterilized by cooking in steam under pressure, either in a special steam cooker or, if this is not available, in an ordinary wash boiler with a tight-fitting cover. If this second cooking is so conducted that the meat is sterilized throughout and the jars are then closed absolutely air-tight, there is no reason why such home-canned poultry should not be perfectly wholesome. If, however, the meat is not heated enough to kill any microorganisms which may have found their way to it, or if there is any chance for others in the air to infect the cooked meat, they may develop in it while it is stored and cause severe poisoning when the meat is used. Experiments are now being made in this office under controlled conditions and with apparatus especially designed to measure interior temperatures in the hope of learning whether or not common household methods of canning heat the food sufficiently to sterilize it entirely.

NUTRITIVE VALUE OF POULTRY.

CHEMICAL COMPOSITION.

The chemical composition of different kinds of poultry and poultry products is given in the table below, which also includes a few other common food materials for purposes of comparison. Data regarding the composition and energy value of poultry are also shown in graphic form in figures 1 and 2.

Average composition of poultry, poultry products, and some other foods.

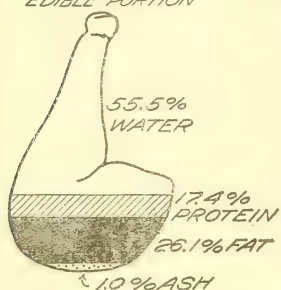
| Kind of food. | Refuse. | Water. | Protein. | Fat. | Carbohydrates. | Ash. | Fuel value. |
|----------------------------------|------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| CHICKENS. | | | | | | | |
| Young: | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Calories.</i> |
| As purchased..... | 18.8 | 55.5 | 17.8 | 7.2 | ..... | 0.9 | 615 |
| Edible portion..... | ..... | 68.4 | 21.9 | 8.9 | ..... | 1.1 | 760 |
| Meat, not including giblets..... | ..... | 66.9 | 22.6 | 10.1 | ..... | 1.1 | 820 |
| Dark meat..... | ..... | 70.1 | 20.8 | 8.2 | ..... | 1.2 | 710 |
| Light meat..... | ..... | 70.3 | 21.9 | 7.4 | ..... | 1.1 | 700 |
| Meat, visible fat removed..... | ..... | 74.5 | 21.8 | 2.5 | ..... | 1.1 | 500 |
| Giblets..... | ..... | 71.0 | 19.8 | 6.4 | ..... | 1.3 | 620 |
| Liver..... | ..... | 69.3 | 22.4 | 4.2 | 2.4 | 1.7 | 620 |
| Heart..... | ..... | 72.0 | 20.7 | 5.5 | ..... | 1.4 | 600 |
| Gizzard..... | ..... | 72.5 | 24.7 | 1.4 | ..... | 1.4 | 505 |
| Broiler: | | | | | | | |
| As purchased..... | 29.1 | 51.2 | 15.5 | 3.3 | ..... | .8 | 415 |
| Edible portion..... | ..... | 69.7 | 20.7 | 8.3 | ..... | 1.1 | 715 |
| Meat, not including giblets..... | ..... | 69.2 | 21.1 | 8.8 | ..... | 1.1 | 740 |
| Giblets..... | ..... | 72.8 | 18.7 | 6.1 | ..... | 1.3 | 590 |
| Capon: | | | | | | | |
| As purchased..... | 17.5 | 46.8 | 17.7 | 17.5 | ..... | 1.0 | 1,035 |
| Edible portion..... | ..... | 56.7 | 21.5 | 21.2 | ..... | 1.2 | 1,255 |
| Meat, not including giblets..... | ..... | 55.8 | 21.6 | 22.1 | ..... | 1.2 | 1,295 |
| Giblets..... | ..... | 63.3 | 20.5 | 14.6 | ..... | 1.3 | 970 |

Average composition of poultry, poultry products, and some other foods—Continued.

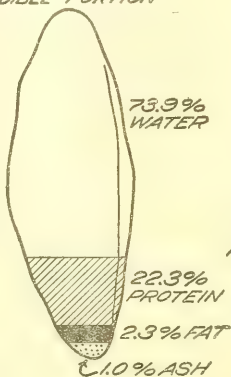
| Kind of food. | Refuse. | Water. | Protein. | Fat. | Car-
bohy-
drates. | Ash. | Fuel
value. |
|---|------------------|------------------|------------------|------------------|--------------------------|------------------|------------------|
| OTHER POULTRY. | | | | | | | |
| Turkey: | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Calories.</i> |
| As purchased..... | 14.3 | 49.2 | 19.0 | 16.2 | ..... | 1.0 | 1,005 |
| Edible portion..... | ..... | 57.4 | 22.2 | 18.9 | ..... | 1.2 | 1,175 |
| Dark meat..... | ..... | 57.0 | 21.4 | 20.6 | ..... | 1.1 | 1,230 |
| Light meat..... | ..... | 63.9 | 25.7 | 9.4 | ..... | 1.3 | 850 |
| Giblets..... | ..... | 56.7 | 17.7 | 23.5 | ..... | 1.2 | 1,280 |
| Dark meat, cooked..... | ..... | 53.7 | 39.2 | 4.3 | ..... | 2.2 | 885 |
| Light meat, cooked..... | ..... | 58.5 | 34.6 | 4.9 | ..... | 1.8 | 830 |
| Duck: | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| As purchased..... | 15.9 | 51.4 | 15.4 | 16.0 | ..... | 1.1 | 930 |
| Edible portion..... | ..... | 61.1 | 18.3 | 19.0 | ..... | 1.3 | 1,110 |
| Meat, not including breast or gib-
lets..... | | 55.5 | 17.4 | 26.1 | | 1.0 | 1,380 |
| Breast..... | ..... | 73.9 | 22.3 | 2.3 | ..... | 1.3 | 500 |
| Giblets..... | ..... | 73.2 | 17.9 | 5.0 | ..... | 1.8 | 530 |
| Duckling: | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| As purchased..... | 16.2 | 43.3 | 12.0 | 28.0 | ..... | .7 | 1,360 |
| Edible portion..... | ..... | 51.7 | 14.3 | 33.4 | ..... | .9 | 1,620 |
| Green goose: | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| As purchased..... | 12.2 | 41.9 | 13.6 | 31.6 | ..... | .8 | 1,535 |
| Edible portion..... | ..... | 48.2 | 15.1 | 36.0 | ..... | .9 | 1,745 |
| Goose: | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| As purchased..... | 11.1 | 48.0 | 14.8 | 25.5 | ..... | 1.0 | 1,310 |
| Edible portion..... | ..... | 54.0 | 16.6 | 28.7 | ..... | 1.1 | 1,475 |
| Meat, not including giblets..... | ..... | 51.8 | 16.2 | 31.5 | ..... | 1.0 | 1,580 |
| Giblets..... | ..... | 70.0 | 20.1 | 8.2 | ..... | 1.7 | 700 |
| Liver..... | ..... | 62.6 | 16.6 | 15.9 | 3.7 | 1.2 | 1,015 |
| Pigeon: | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| As purchased..... | 13.6 | 55.2 | 19.7 | 9.5 | ..... | 1.3 | 745 |
| Edible portion..... | ..... | 64.0 | 22.8 | 11.0 | ..... | 1.5 | 865 |
| Meat, not including giblets..... | ..... | 63.2 | 22.9 | 12.1 | ..... | 1.4 | 910 |
| Giblets..... | ..... | 68.1 | 22.2 | 5.2 | ..... | 2.3 | 615 |
| Squabs: | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| As purchased..... | 15.6 | 49.0 | 15.7 | 18.6 | ..... | 1.3 | 1,045 |
| Edible portion..... | ..... | 58.0 | 18.6 | 22.1 | ..... | 1.5 | 1,240 |
| Meat, not including giblets..... | ..... | 56.6 | 18.5 | 23.8 | ..... | 1.4 | 1,310 |
| Giblets..... | ..... | 69.8 | 19.8 | 7.2 | ..... | 2.0 | 655 |
| Guinea hen: | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| As purchased..... | 16.4 | 57.7 | 19.4 | 5.4 | ..... | 1.1 | 570 |
| Edible portion..... | ..... | 69.1 | 23.1 | 6.5 | ..... | 1.3 | 685 |
| Meat, not including giblets..... | ..... | 68.9 | 23.4 | 6.5 | ..... | 1.3 | 690 |
| Giblets..... | ..... | 69.9 | 20.8 | 7.1 | ..... | 1.3 | 665 |
| Pheasant: | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| As purchased..... | 12.0 | 61.5 | 21.5 | 4.2 | ..... | 1.0 | 560 |
| Edible portion..... | ..... | 69.9 | 24.4 | 4.8 | ..... | 1.1 | 640 |
| Meat, not including giblets..... | ..... | 70.0 | 24.7 | 4.6 | ..... | 1.1 | 635 |
| Quail: | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| As purchased..... | 10.5 | 59.0 | 22.3 | 6.1 | ..... | 1.4 | 655 |
| Edible portion..... | ..... | 65.9 | 25.0 | 6.8 | ..... | 1.6 | 730 |
| Meat, not including giblets..... | ..... | 66.3 | 25.4 | 7.0 | ..... | 1.4 | 745 |
| Giblets..... | ..... | 63.0 | 21.8 | 6.2 | ..... | 2.3 | 650 |
| PRESERVED POULTRY MEAT. | | | | | | | |
| Potted turkey..... | ..... | 56.0 | 17.2 | 22.0 | ..... | 3.0 | 1,210 |
| Potted chicken..... | ..... | 56.1 | 19.4 | 20.3 | ..... | 2.5 | 1,180 |
| Canned chicken soup..... | ..... | 87.1 | 2.9 | 3.3 | 5.1 | 1.6 | 280 |
| Canned boned chicken..... | ..... | 57.6 | 27.7 | 12.8 | ..... | 2.2 | 1,025 |
| Canned quail..... | ..... | 66.9 | 21.8 | 8.0 | 1.7 | 1.6 | 755 |
| Pâté de foie gras..... | ..... | 41.3 | 13.6 | 38.2 | 4.3 | 2.6 | 1,885 |
| OTHER KINDS OF FOOD FOR COMPARISON. | | | | | | | |
| Beef, sirloin steak, as purchased..... | 12.8 | 54.0 | 16.5 | 16.1 | ..... | .9 | 955 |
| Beef, brisket, as purchased..... | 23.3 | 41.6 | 12.0 | 22.3 | ..... | .6 | 1,130 |
| Lamb chops, as purchased..... | 14.8 | 45.3 | 16.0 | 24.1 | ..... | .8 | 1,275 |
| Mutton, leg, as purchased..... | 18.4 | 51.2 | 15.1 | 14.7 | ..... | .8 | 875 |
| Pork, chops, as purchased..... | 19.7 | 41.8 | 13.4 | 24.2 | ..... | .8 | 1,230 |
| Pork, salt fat, as purchased..... | 11.2 | 17.6 | 7.4 | 59.6 | ..... | 5.1 | 2,565 |
| Halibut, fresh, steaks, as purchased..... | 17.7 | 61.9 | 15.3 | 4.4 | ..... | .9 | 460 |
| Mackerel, salt, as purchased..... | 19.7 | 34.8 | 13.9 | 21.2 | ..... | 10.4 | 1,115 |
| Oysters, solid..... | ..... | 88.3 | 6.0 | 1.3 | 3.3 | 1.1 | 220 |
| Eggs, as purchased..... | 11.2 | 65.5 | 11.9 | 9.3 | ..... | .9 | 595 |
| Milk..... | ..... | 87.0 | 3.3 | 4.0 | 5.0 | .7 | 315 |
| Butter..... | ..... | 11.0 | 1.0 | 85.0 | ..... | 3.0 | 3,490 |
| Cheese, as purchased..... | ..... | 34.2 | 25.9 | 33.7 | 2.4 | 3.8 | 1,890 |
| Wheat flour..... | ..... | 12.0 | 11.4 | 1.0 | 75.1 | .5 | 1,610 |
| Wheat bread, white..... | ..... | 35.6 | 9.3 | 1.2 | 52.7 | 1.2 | 1,175 |
| Beans, dried..... | ..... | 12.6 | 22.5 | 1.8 | 59.6 | 3.5 | 1,565 |
| Potatoes, as purchased..... | 20.0 | 62.6 | 1.8 | .1 | 14.7 | .8 | 305 |
| Apples, as purchased..... | 25.0 | 63.3 | .3 | .3 | 10.8 | .3 | 215 |

The nutritive value of any food material as purchased depends not merely on its total composition but on the proportion of edible to inedible material which it supplies.

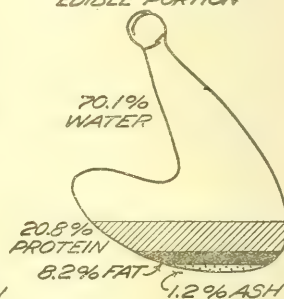
**DUCK LEG AND
SECOND JOINT**
EDIBLE PORTION



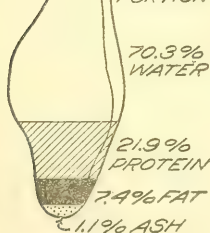
DUCK BREAST
EDIBLE PORTION



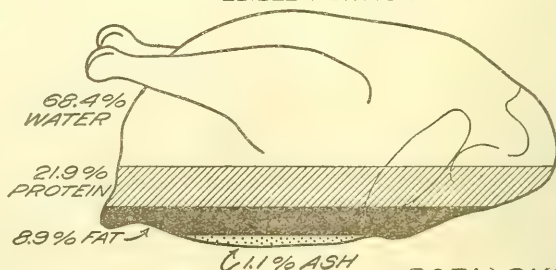
**CHICKEN LEG AND
SECOND JOINT**
EDIBLE PORTION



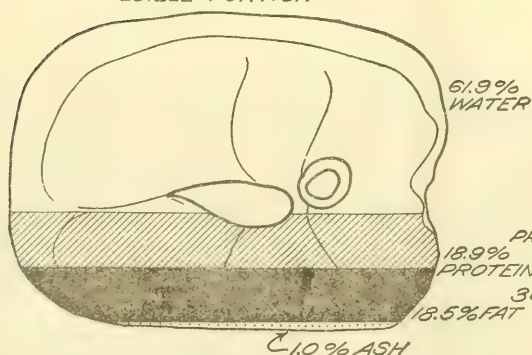
**CHICKEN
BREAST**
EDIBLE PORTION



WHOLE CHICKEN
EDIBLE PORTION



BEEF STEAK
EDIBLE PORTION



PORK CHOP
EDIBLE PORTION

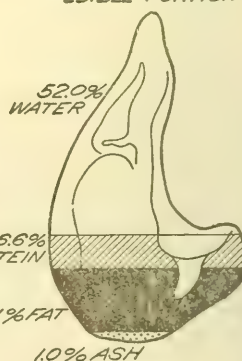


FIG. 1.—The composition of poultry in comparison with other foods.

The edible portion of poultry consists chiefly of the muscular tissue, the fat, and the edible entrails (giblets). Like all meats, it

is made up of water, protein, and fat, with a very small amount of carbohydrates in the form of glycogen, and a small amount of mineral matter, or ash. The nature of these nutrients and the uses to which they are put in the body have been discussed in another publication.¹

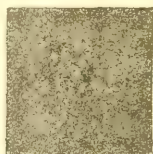
The differences in composition between different kinds of poultry are not very marked. (See fig. 1.) There are fully as great differences between specimens of the same kind of birds at different ages as between different kinds of birds. In general, the younger birds contain larger amounts of refuse and water than the older ones and have a correspondingly low proportion of actual nutrients. Individual birds of any kind or age may vary greatly in the amount of water or fat included in their flesh, and this fact, of course, affects their food value as well as their tenderness and flavor. In spite of all these differences the following figures may be taken as roughly representing the general composition of dressed poultry: The refuse, which includes the head, feet, bones, and inedible entrails, makes up from 15 to 20 per cent, and the edible portion, including the skin, 80 to 85 per cent of the weight of the dressed bird. The edible portion itself consists of 55 to 65 per cent of water, 20 per cent of protein, from 10 to 35 per cent of fat, and 1 to 2 per cent of mineral matter.

In spite of their general similarity there are some characteristic differences in the composition of different kinds of poultry. The light-fleshed birds are richer in protein and poorer in fat than the others. In chickens, and probably in all the light-fleshed varieties, the young birds yield a larger proportion of protein and a smaller proportion of fat than the older ones of the same kind, while in the dark-fleshed varieties, such as duck and goose, the young are richer in fat and poorer in protein.

Some of these differences in composition in the various kinds of poultry are great enough to be carefully considered in planning dietaries. If chicken, with its 8 per cent of fat, were substituted in a menu for green goose, with its 36 per cent, or turkey, with 22 per cent protein, for duckling, with .14 per cent, the proportion of building material and fuel furnished to the body might be noticeably changed. But too much importance should not be put on the differences between closely related birds, such as chicken, capon, and turkey, for they are too slight to affect seriously the nutritive value of the diet under ordinary circumstances. Moreover, the greater nutritive value which one kind seems to possess may be counterbalanced by greater losses in cooking, by leanness or fatness of the individual specimen, or by higher price. The consideration of price is so important that it will be discussed at length in a later section.

¹ U. S. Dept. Agr., Farmers' Bul. 142 (1910).

STANDARD FOR COMPARISON

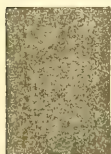
1,000 CALORIES
PER POUND

WHOLE CHICKEN



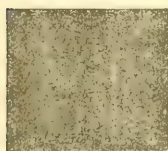
760 CAL.

CHICKEN BREAST

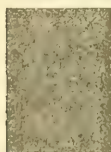


700 CAL.

BEEF STEAK

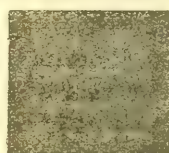


1,100 CAL.

CHICKEN LEG
AND SECOND JOINT

710 CAL.

WHOLE DUCK



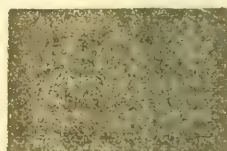
1,110 CAL.

DUCK BREAST



500 CAL.

PORK CHOP



1,530 CAL.

DUCK LEG
AND SECOND JOINT

1,380 CAL.

FIG. 2.—The energy value of poultry in comparison with some other foods.

As the figures in the table and the diagrams in figure 2 show, poultry has an energy value much like that of other flesh foods, and, like that, varying with individual kinds; chicken, for example, averages less energy value per pound than duck, owing to the fact that it is usually less fat. In chicken the light and dark meat have much the same energy value per pound, while in duck the leg and second joint have a higher energy value than the breast, being almost equal to pork chop in this respect.

DIGESTIBILITY AND HEALTHFULNESS.

There is a popular idea that different kinds of poultry vary considerably in digestibility or healthfulness. Such ideas, it may be said in passing, most often refer merely to the behavior of food in the stomach—whether or not it leaves that organ quickly and without causing discomfort—and take no account of the equally important intestinal digestion. In the case of poultry of different kinds, scientific investigation indicates that there is much less difference than is commonly supposed, and that nearly all of the nutrients and energy of poultry, as of other meats, are utilized by the healthy, normal body.

Such a statement does not take account of the ease and quickness of digestion nor of the effect that some of the characteristics of the different meats might have in certain forms of disease, and these considerations must be borne in mind in discussing the value of different kinds of foods in special cases.

For example, it has been said that poultry, veal, and lamb are more healthful than red meats (beef), because the so-called "light" meats contain less of certain nitrogenous extractives supposed to be harmful in rheumatism, gout, and certain kidney diseases. Recent investigations indicate that the differences in this regard between the two classes of meat are inconsiderable, and that they are quite as much in favor of the red as the light meats.

There is also a theory that the light meat of chicken, turkey, etc., is more easily digested, because more tender, than the dark. A glance at the figures for chicken and turkey, in the table, will show that the light meat of these birds, and especially of turkey, contains more protein and less fat than the dark, and that, since fat is sometimes less easily digested than protein, they may yield more nourishment for the same amount of digestive effort. Very likely the popular idea that the breast of duck is much more digestible than other parts of the bird may be explained by the fact that it contains 5 per cent more protein and 24 per cent less fat than the other parts. These differences in nutritive value seem to depend on the chemical composition rather than on the texture of the fibers, and are not ordinarily of practical importance.

Not much is accurately known regarding the digestibility of poultry cooked in different ways, but there is little reason to suppose that the differences are great enough to be of significance to healthy persons. In some recent experiments with man it was found that boiled chicken left the stomach more quickly than roasted. This does not indicate that the boiled chicken was more thoroughly digested, but merely that it was more quickly acted upon by the digestive mechanism of the stomach, and that, therefore, it might be a more desirable form for persons suffering from gastric indigestion. Fried chicken, like fried foods in general, has the reputation of causing more digestive disturbance than that cooked in other ways. It is not yet definitely known to what extent this is true, or, if true, the reason for it. One suggested explanation is that the layer of fat surrounding the food prevents the gastric juice from acting on it and delays digestion until the fat itself is acted upon in the intestine; another is acrolein if developed in overcooked fat is irritating to the lining of the digestive organs, just as in the fumes from burning fat it irritates the eyes and throat.

One occasionally hears of poisoning from chicken pie. Many persons believe that such trouble is due to the fact that the pie was baked without having holes made in the crust, but this theory seems to have no foundation. In an experiment in this office in which two pies exactly similar except that one was made with an unpierced and the other with a pierced crust, were baked at the same temperature, it was found that they lost equally in weight during baking, cooled at practically the same rate, and were in every way identical except that less juice ran out of the one with the pierced crust. Undoubtedly there are occasional cases of chicken-pie poisoning, but they are probably no more common than poisoning from other "made" dishes, including some which contain no animal food. All such poisoning is due to microorganisms which have accidentally gained access from dust, dirty fingers, or in some similar way. They may have withstood the heat of cooking or entered the food after it left the oven. In chicken pie, the meat might have become infected between the first cooking and the time the pie was made. Fortunately such poisoning can be prevented by care and cleanliness in handling the food.

COST OF POULTRY.

The cost of poultry, like that of all meats, has been rising more or less steadily during the last few years, but as no complete records are kept of the market prices of different varieties, it is hard to make accurate statements regarding the actual price. The only definite figures found are those for chickens, collected by the Bureau of Labor Statistics. For the year 1914 the retail price of chickens of good quality, marketed dressed, ranged from 15 to 28 cents per

pound. It was lowest in the late autumn and early winter, and highest in midsummer, extremes which seem to be in close relation to the natural supply. The price of live chickens was slightly lower, but not enough so to make it worth while for the ordinary householder to buy birds alive merely on this account.

Local conditions still have influence on retail prices, especially where retailers or housekeepers buy directly from the breeders, and probably home-grown poultry is somewhat cheaper in the Southern States, where less care is required, and in the Central States, where chickens are kept in great numbers, than in other parts of the country.

Even at the same place and time the retail prices of birds are very variable. If a dealer keeps an attractive looking shop, well supplied with perishable, fancy, and out-of-season goods, and is ready to deliver them anywhere at a moment's notice, he must, other things being equal, charge more than a neighboring one who keeps a less expensive stock and sends his delivery wagon on its rounds only once or twice a day. Each purchaser must decide for himself whether or not he can afford to pay for the extra convenience and range of choice of the more expensive market. He will, however, always find it good economy to trade only in markets which have ample facilities for caring for their stock and which are kept scrupulously clean.

It is almost impossible to estimate what relation retail prices bear to the current wholesale prices, but they may occasionally run as high as twice the latter. Of course, in the country, especially from farms where poultry raising is a secondary affair, good birds can sometimes be bought for little more than the wholesale prices.

The less common kinds of poultry, such as squab and pheasant, which are still raised only in small numbers and often at considerable cost and risk, are naturally expensive beyond all comparison with the standard kinds.

Although the market price is the most important factor in determining whether poultry is a cheap or a dear food, it is not the only one, and the real cost of poultry as food depends not on its price per pound, but on the price paid for its actual nutrients. Judged by this standard, well-grown, moderately fat birds are more economical at a given price per pound than either very young or very fat ones. (See p. 28.)

In general, it may be said that low-priced chicken, turkey, goose, pigeon, and guinea fowl are as economical as medium-priced beef and mutton. Chicken and turkey at out-of-season prices, capon, duck, duckling, and green goose are more expensive, while pheasant, quail, and squab are among the most expensive of all meats.

SUMMARY.

Chicken is by far the most common kind of poultry in the United States, but capon, turkey, duck, goose, and squab are also often used for food, while guinea fowl, pheasant, pigeon, quail, and partridge are fairly well known. In all of them table quality depends primarily on tenderness and flavor, and these, in turn, are influenced by age, sex, exercise, food, and care. Freshness is also an important factor, but this is not merely a question of how long a bird has been dead, but rather of how far developed are the chemical and bacteriological changes which, when they are carried too far, cause what we call spoiling or decomposition in the meat. The microorganisms which cause dangerous changes are likely to be introduced by careless and dirty handling, and for this reason cleanliness should be insisted on. The changes take place most rapidly in the presence of warmth and moisture. Hence cleanliness, cold, and dryness are at the bottom of all the methods of caring for poultry on the farm, in the warehouse, at the market, and in the home.

The methods of cooking poultry are, in general, the same as those for other kinds of meat. The tougher the bird, the more cooking will be needed to make it tender and easily digested, and the larger it is, the more heat will be required to cook it thoroughly. Canned and potted poultry are prepared in much the same way as freshly cooked dishes, then sterilized and sealed, and when properly put up do not differ essentially in food value from similar fresh foods.

As regards composition, poultry does not differ as much as is commonly supposed from other meats. Individual kinds and specimens, of course, vary in the relative amounts of inedible material or of protein and fat contained, and there are certain flavors present in poultry which differ from those in other meats; but these differences are not important in ordinary diet. The difference in digestibility between poultry and other meats or between various kinds of poultry is very slight. The latter probably depends largely on the amount of fat contained, the fatter sorts being, perhaps, less easily digested, but the distinctions are unimportant for healthy persons.

The relative cost of different kinds of poultry depends primarily on the price, but also on the proportion of edible to inedible material and the thoroughness with which the edible portions can be utilized. Well-grown birds with good-sized masses of moderately fat flesh are more economical than either young or over-fattened ones. At ordinary retail prices, full-grown chicken is the only poultry which compares in real economy with the cheaper cuts of beef and pork, but young chicken, medium-sized turkey, goose, and guinea fowl are often as economical as the more expensive grades of other meats. When the birds can be obtained for little more than the cost of care and feeding, as sometimes happens on farms, they are, of course,

much more economical. In any case where the price allows them to be used, they furnish a pleasant and wholesome means of varying the meat dishes in the ordinary diet.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 468

Contribution from States Relations Service
A. C. TRUE, Director.



Washington, D. C.

PROFESSIONAL PAPER

January 17, 1917

POTATOES, SWEET POTATOES, AND OTHER STARCHY ROOTS AS FOOD.

By C. F. LANGWORTHY, *Chief, Office of Home Economics, States Relations Service.*

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INTRODUCTION.

Among vegetable food products those plants are very important which lay up a supply of edible material during the favorable days of summer in the form of thickened roots or underground stems and bulbs. These root vegetables have different habits and characteristics and accordingly belong to separate botanical groups; some are well known the world over, while others are rarely seen outside of their native country. For convenience in discussing food problems they may be divided into two groups: (1) Those which, like potatoes and sweet potatoes, contain a fairly high proportion of food material, chiefly starch and other carbohydrates; and (2) those like beets, turnips, parsnips, and so on, which, although they resemble the first group in many ways, nevertheless are different from them in other respects, being more succulent, quite commonly of higher flavor, and used in the diet in a somewhat different way. This group is discussed in another department bulletin.¹

¹ U. S. Dept. Agr., Bul. 503.

NOTE.—This bulletin, which is a revision in part of Farmers' Bulletin 295, summarizes the results of experimental and other data regarding the nature and uses of potatoes and other starchy roots as food, and is primarily of interest to housekeepers and to teachers and students of home economics.

In the pages which follow attention is paid particularly to the potato, sweet potato, and Jerusalem artichoke; and more briefly to the yam, cassava, dasheen, taro, and yautia—roots commonly known in our island possessions and to at least a limited extent in the United States proper. It is almost needless to say that the white, or common, potato, judged both by the extent to which it is grown and by its food value, is by far the most important representative of the starchy-root group. Next in importance comes the sweet potato, which is well known all over the country and is a staple root crop in a large area of the more southern portion of the Southern States. What a prominent place these two together hold in the diet may be seen from the fact that in 376 American dietary studies they were found to furnish an average of 12.5 per cent, or about one-eighth of the total food material, and 8.3 per cent, or about one-twelfth of all the carbohydrates eaten.

POTATOES.

HISTORY AND EXTENT OF CULTIVATION.

The potato, called in different regions white potato, Irish potato, English potato, or round potato, was first introduced into Europe from America toward the close of the sixteenth century by both the Spaniards and the English, in the latter case as a result of the expeditions sent by Raleigh to the Virginia colony. It is believed to be a native of western South America, where wild forms are still found.

In 1915 the potato crop in the United States totaled, in round numbers, 359,000,000 bushels, valued at \$221,000,000. Part of the annual crop is used for feeding farm animals, and the poorer grades of tubers for manufacturing purposes, but the greater part is served on our tables.

STRUCTURE AND COMPOSITION.

The food value and cooking quality of a potato depend upon its structure and composition. The tuber is in reality a modified stem, shortened and thickened to form a storehouse for material held in reserve for the early growth of new plants. As in all other plant forms, the framework of the tuber is made up of cellulose, or crude fiber. This carbohydrate forms the walls of the multitude of tiny cells, which make up the structure of the tuber and which vary in shape and size in different sections of the tuber according to the part they play in its life. The tuber has several distinct parts not all equally nutritious. If a crosswise section of a raw potato be held

up to the light four distinct parts may be seen (fig. 1). The outer skin consists of a thin, grayish-brown, corky substance corresponding roughly to the bark of an above-ground stem, which is of

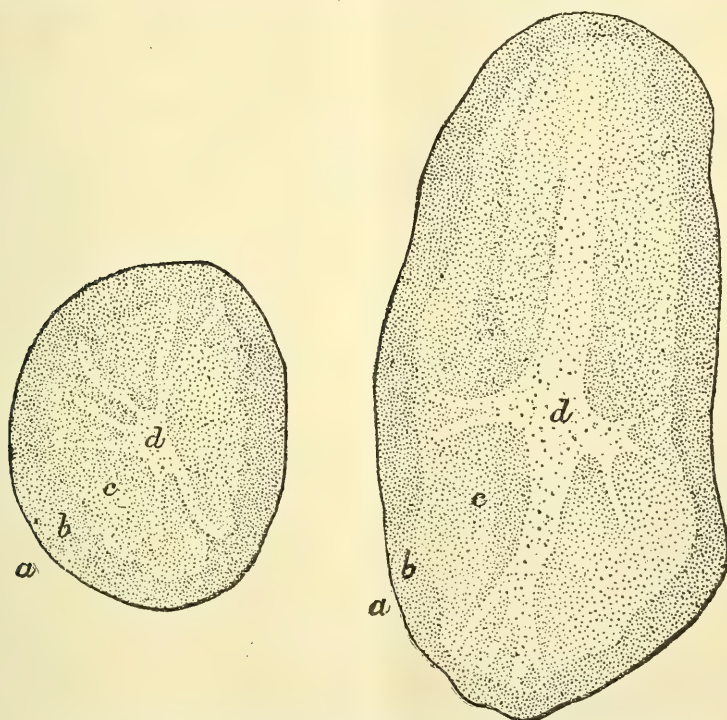


FIG. 1.—Transverse and longitudinal sections of the potato: *a*, Skin; *b*, cortical layer; *c*, outer medullary layer; *d*, inner medullary area.

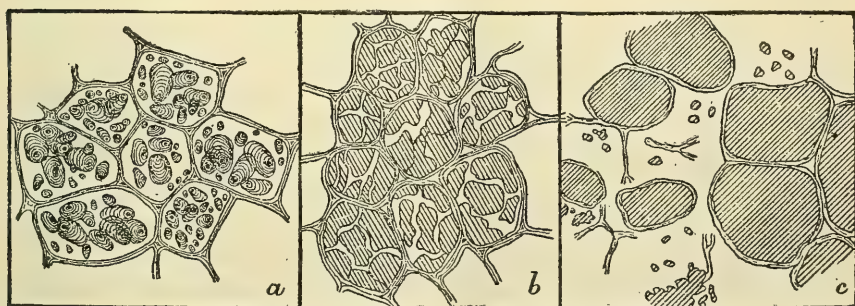


FIG. 2.—Changes of starch cells in cooking: *a*, Cells of a raw potato with starch grains in natural condition; *b*, cells of a partially cooked potato; *c*, cells of a thoroughly boiled potato.

little value as food (see p. 5). The cortical layer (bark) is next to the skin and may be from 0.12 to 0.5 inch in thickness. This layer is slightly colored and turns green if exposed to the light for some time, thus showing its relation to the tender green layer beneath

the bark of above-ground stems. Besides starch the cortical layer contains a higher percentage of the mineral matter, soluble carbohydrates, soluble nitrogenous matter, and acid substances than the tuber as a whole. In the interior or flesh of the tuber lie the stored starch grains (see fig. 2). This portion is made up of two layers known as the outer and inner medullary or pithy areas. The outer one forms the main bulk of a well-developed potato and contains the greater part of the food (starch and other ingredients), the proportion of the different carbohydrates¹ varying with the stage of growth, degree of ripeness, and similar factors. The inner medullary area, sometimes called the core, appears in a cross section of the tuber to spread irregular arms up into the outer area so that its outline roughly suggests a star. It contains slightly more cellulose and water and food material than the outer medullary portion. If it is overdeveloped, the potato is likely to be soggy when cooked.

The relative proportions of the different parts of the tuber vary with variety and doubtless other factors. According to determinations made in connection with the department's studies of the food value of local-grown potatoes, it was found that the actual skin, as distinguished from the portion usually pared off and sometimes called the peel, made up about 2.5 per cent of the whole, and the cortical layer 8.5 per cent, leaving 89 per cent for the medullary areas. According to average values reported by French observers,² the skin made up 8.8 per cent of the tuber and the cortical layer 36.2 per cent, while the outer medullary area made up 34.2 per cent and the inner medullary area 15 per cent, or the two together 49.2 per cent.

The composition of the potato varies with the variety, the character of the soil, the climate, and other conditions under which it grows—a fact taken advantage of when the grower plants potatoes in sandy soil with the expectation of getting a mealy tuber. The needs of the potato plant, and consequently the composition of the tuber, also vary at different stages of its growth, a young potato being more watery and less starchy than one fully ripe. As a result of many analyses the average percentages of the different food ingredients in potatoes are now well established. The figures in Table I show the composition of raw and cooked potatoes and, for comparison, the composition of white bread.

¹ In this connection it is well to recall that the carbohydrates (starch, the different kinds of sugar, pentoses, cellulose, etc.) are all closely related and that under the influence of ferments, certain acids, heat, or other agency, an insoluble form, such as starch, may be changed into a soluble form, such as sugar, or vice versa—a kind of change which takes place in nature, as for instance in the developing and ripening tuber or seed and is also important in food manufacture and in digestion and assimilation.

² Coudon and Bussard. *Ann. Sci. Agron.*, 2. ser., 3 (1897), I, No. 2, p. 250.

TABLE I.—Composition of raw and cooked potatoes.

| Kind of food. | Refuse. | Water. | Protein. | Fat. | Carbohydrates. | | Ash. | Fuel value per pound. |
|--|----------------|----------------|----------------|----------------|---------------------|----------------|----------------|-----------------------|
| | | | | | Sugar, starch, etc. | Crude fiber. | | |
| | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Calories.</i> |
| Potato, as purchased..... | 20.0 | 62.6 | 1.8 | 0.1 | 13.8 | 0.9 | 0.8 | 305 |
| Potato, edible portion..... | | 78.3 | 2.2 | .1 | 18.0 | .4 | 1.0 | 375 |
| Potato, boiled..... | | 75.5 | 2.5 | .1 | 20.3 | .6 | 1.0 | 430 |
| Potato, mashed and seasoned..... | | 75.1 | 2.6 | 3.0 | 17.8 | | 1.5 | 490 |
| Potatoes, fried in fat (potato chips)..... | | 2.2 | 6.8 | 39.8 | 46.7 | | 4.5 | 2,595 |
| Baked potatoes..... | | 74.0 | 3.0 | | 22.0 | | 1.0 | 455 |
| Potato starch (potato flour)..... | | 7.1 | .1 | | 92.8 | | | 1,685 |
| Potato meal and flakes..... | | 7.6 | 4.6 | .3 | 82.3 | 1.8 | 3.4 | 1,620 |
| Potato, evaporated..... | | 7.1 | 8.5 | .4 | 80.9 | | 3.1 | 1,640 |
| White bread, for comparison..... | | 35.3 | 9.2 | 1.3 | 52.6 | .5 | 1.1 | 1,185 |

As the table shows, the refuse, that is, the part removed in preparing potatoes for eating either before they are cooked or at the table, makes up on an average about one-fifth of the whole tuber, and the part commonly eaten, that is, the edible portion, four-fifths. Water is the most abundant constituent of the potato and forms about three-fourths of the edible substance. The remainder is mostly starch, though there is a little nitrogenous matter (protein) and fat. The amount of mineral matter (ash) is actually small, but as compared with that in other foods it is relatively high, and is of much value in nutrition. Figure 3 represents in graphic form the composition of the edible portion of the potato and shows even more plainly than the table that the bulk of the potato tuber is water.

Theoretically, the skin is the only refuse or inedible material in the potato, but in practice a considerable part of the edible portion is removed with it (fig. 4). When the surface is irregular, or the tubers have shriveled in storage, a much greater proportion of the flesh is likely to be cut off with the skin in paring than is the case when the tubers are smooth and in good condition. It is estimated that in paring raw potatoes by household methods the loss is about 20 per cent. This includes not only all of the skin and the cortical layer, but also 9 per cent of the flesh. When we recall how large is the proportion of water and how low that of nutrients in the tuber, and also that the larger proportion of the protein and mineral mat-

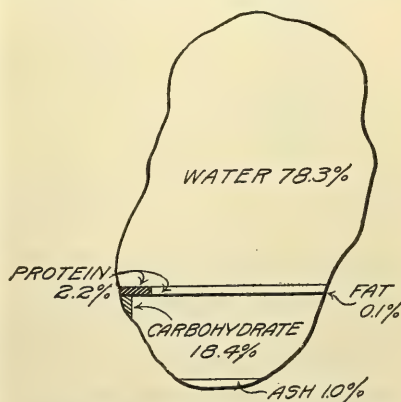


FIG. 3.—Percentages and loss in digestion of nutrients of the potato. Shaded portion shows a loss in digestion of 15 per cent of the protein and 1 per cent of the carbohydrates.

ters is in the outer layers, this waste appears more important than is generally realized. The mechanical potato parers now available usually remove the skin with much less loss of edible material, and they have the further advantage of saving time for all but very skillful workers. There are a number of kinds on the market, which either pare the potatoes in much the same way as is done by hand or else rub off the skin.

The carbohydrates stored in the potato form 18.4 per cent of the edible portion. Most of this is starch, though there are also small quantities of soluble carbohydrates or sugars. Young tubers have a larger proportion of sugars and less starch than mature potatoes. If the tuber lies in the ground the starch content increases for a time, but when it begins to sprout part of the starch is converted by a ferment in the tuber into soluble glucose. Thus, both young or early

potatoes and old ones have a smaller proportion of starch and more soluble sugars than well-grown but still fresh tubers.

Less than 0.5 per cent of the carbohydrates is cellulose, yet one sometimes hears the statement that potatoes are indigestible on account of the large quantities of cellulose which they contain. In reality there is no more cellulose in the po-

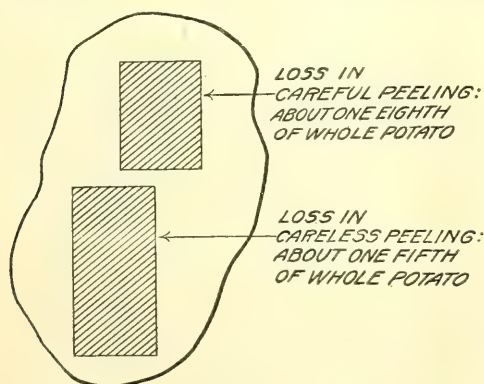


FIG. 4.—Loss of weight in peeling potatoes.

tato than occurs in most of the cereals and in other vegetable foods, and so such a criticism of the potato has no warrant in fact.

Besides the carbohydrates mentioned, potatoes also contain a little pectose, the French investigators quoted above reporting the presence of 0.2 to 0.4 per cent. Pectose, which is so important in jelly making when it occurs in quantity, as in fruits, is believed to have practically the same food value as other carbohydrates.

Fat appears in such small quantities in potatoes that it may be practically neglected in discussing their food value, especially as the greater part occurs in a waxlike form in the inedible skin.

The protein bodies are rather small in quantity, as compared with those of cereals and such vegetables as peas and beans, and only about 80 per cent of the total amount present is available protein; that is, protein in a form which can be used for the building and repair of body tissues. This means that a pound of potatoes furnishes only about 0.2 of an ounce of available protein and emphasizes the state-

ment that potatoes alone make a very incomplete diet; only a very small amount of nitrogenous material would be obtained from a quantity of potatoes sufficient to supply the body with all the energy-yielding material required.

The protein has been found to consist in part of a form of globulin, for which the name tuberin has been suggested. Other nitrogenous compounds present are a proteose, asparagin, and amino acids.

The most important mineral matters found in potatoes are potassium and phosphorus compounds. There are several organic acids (such as citric, tartaric, and succinic acid¹), which vary in tubers of different ages and account in some measure for the flavor of potatoes.

The potato, like many other foods, also contains minute amounts of physiologically active substance or substances valuable in nutrition and commonly called vitamins.²

The question is often asked, why the outer surface of freshly pared potatoes turns brown. According to experimental evidence this change is due to the action of enzymes, or ferments, naturally present in the plants. In the presence of the oxygen of the air they work upon tannin-like bodies in the tuber in such a way that the latter change color. This browning may be prevented by putting the pared tubers into plain cold water or, better, into salted water.

COOKING.

When boiled, the temperature of the interior of the potato does not exceed 212° F. (the temperature of boiling water). When baked, the temperature of the interior of the potato reaches 212° F., but does not exceed it, if cooked only until it is done. If overcooked, the temperature may be considerably higher, which may account for changes which cause the peculiar taste of overbaked potatoes. The heat affects the various constituents of the potato in different ways. The water expands into steam, part of which evaporates from the surface. Within the minute cells making up the tuber it presses so hard against the walls that the tough cellulose is ruptured, just as any air-tight vessel may be broken by the pressure of expanding steam. The starch grains inside the cells are thus released, some of them being also disintegrated, while part are changed into the soluble

¹ In proximate analyses such as those given on page 5 these acids would be included in the "carbohydrates," a matter of analytical convenience, not of chemical accuracy. Proximate analyses, it should be remembered, are designed to show group characteristics, and not the individual compounds which more detailed analyses would deal with.

² The vitamins are apparently in part dissolved in the juice and in part stored with the starch of the cortical layer of cells. Exactly what is their nature and the part they play in human nutrition is not yet fully understood, but recent investigations suggest that they do important work in regulating cell metabolism and are possibly concerned in the process of growth. It is not unlikely due to some of these compounds that potatoes prevent scurvy on shipboard or in other circumstances where fresh fruits and vegetables are not to be had.

form of dextrin by the heat, and part absorb water and swell. Protein coagulates or hardens, much as the white of egg does when cooked, and at least a part of it is broken down into simpler bodies. The mineral salts are probably less affected, but some are broken down and form new compounds, at least a little sulphur being driven off in volatile form when the potatoes are boiled. As is the case with other vegetables, this sulphur no doubt contributes to the odor of the potatoes while cooking. It is the sum of these and minor changes which accounts for the difference of flavor and texture in a raw and a cooked potato. As may be seen from the figures in Table I (p. 5), the cooked potatoes, which contain no added fat or other materials, do not differ much from the raw as regards composition. The effects of cooking on the mechanical condition of the potato cells is shown in figure 2, page 3.

The figures show the great changes in the mechanical condition of the potato flesh under the influence of heat, the broken cell walls and the increased bulk of the starch grains being particularly noticeable. The mealy, soft, porous mass of the cooked potato is in a favorable condition for the action of the digestive juices, as moisture readily penetrates to all parts of it, while this is not the case with the rather tough flesh of the uncooked tuber. It is commonly said that raw starch, like that found in the potato, is not digestible, but investigations indicate that this is not the case and that the digestive juices will dissolve the starch, provided the cell walls are ruptured by chewing or in any other way so that the ferments may come in contact with it.

One of the great advantages in cooking potatoes and similar vegetable foods is the improvement in flavor. This is due in part to the development of the cooked-starch taste, which is much more pleasant than that of raw starch. It is also due to changes in the flavor-yielding bodies. Raw potatoes, especially old ones, often have a decidedly bitter and disagreeable flavor (see p. 13), which is less marked after cooking, because some of the flavor-yielding bodies are removed. The reason why so many housekeepers consider boiling better for old potatoes than baking is that the boiling extracts more of the disagreeable elements. This also explains the common custom of soaking old potatoes before cooking and that of throwing away the water in which potatoes have been boiled.

There are also disadvantages in the results of cooking, and, though they are less important than the advantages, they influence the food value somewhat. There is some reason for believing that the protein of the potato is stiffened by heat and becomes less readily digested than when raw. A much more serious matter is that considerable quantities of the nutrients may be lost during cooking (fig. 5). Several series of experiments have been made by investigators of the De-

partment of Agriculture and by others to determine just how much of the different nutrients is lost when the potatoes are cooked in various ways. It was found that the loss is much the same whether the water is hard or soft. Soaking the potatoes in water before boiling greatly increases the amount of nutrients extracted. When they are put in cold water and brought to a boil they lose twice as much of their protein (15.8 per cent) as when they are plunged at once into boiling water; the loss of mineral matter is about 18 per cent of the total present by both methods. On account of these losses in boiling potatoes many persons consider steaming preferable.

The tests just noted were all made with pared potatoes, but another series was made with unpared ones, in which it was found that when boiled in their jackets potatoes lose only 1 per cent of their protein and a little over 3 per cent of their ash, no matter what the temperature of the water is at the start. Almost no starch is removed when potatoes are boiled in their skins, but when pared the mechanical action of the boiling water wears off the outer surface, and in this way as much as 3 per cent of the carbohydrates may be lost.

Evidently, then, by far the most economical way to boil potatoes is in their jackets. When they are cooked this way they should, of course, be thoroughly scrubbed before cooking and are sometimes, particularly in the case of new potatoes, scraped to remove the greater part of the skin. In some families it is a common practice to remove a section of the skin at each end of the potato or to pare a ring around the middle of the tuber so that the moisture may escape and the cooked potato may not become soggy on standing. If they are pared before cooking, they should be placed directly in hot water.

When baked in their skins, potatoes probably undergo much the same changes as in boiling, but they lose practically none of their ingredients except a little water which evaporates through the skin. Some of their moisture changes to steam inside, and unless the potatoes are to be eaten immediately it must be allowed a way of escape or it will change back to water and make the potatoes soggy. This explains the practice of breaking, cutting, or pricking the skin of the baked potatoes when they are taken from the oven.

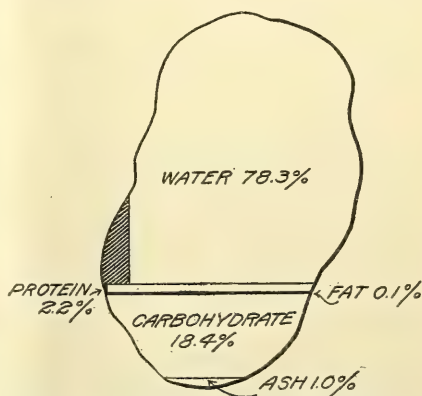


FIG. 5.—Composition of the potato and loss of nutrients when it is boiled without paring. Shaded portion shows loss in boiling of 2.8 per cent of the water and 1 per cent of the protein. Unless portions break off no starch (carbohydrate) is lost. A little over 3 per cent of the ash is lost in boiling.

When raw potatoes are fried they lose some water by evaporation and may gain a considerable amount of fat. The thinner the pieces the greater will be both these changes and the crisper the cooked potato. Fried potato chips, as the table on page 5 shows, contain only 2 per cent of water and 39.8 per cent of fat, whereas the raw tubers contain about 78 per cent of water and 0.1 per cent of fat.

Potatoes may be prepared for the table in a great many ways, and this is an advantage, as it helps to give variety to the diet. Directions for some of these, along with methods of cooking other vegetables as well, have been published elsewhere.¹ When other materials are added to the potatoes—for example, when boiled potatoes are mashed with milk and butter—the composition of the finished dish will be that of plain boiled potatoes plus the nutrients in the materials added. Mashed potatoes differ in color and consistency according to the way in which they are handled. If the cooked potato is simply run through a ricer, it yields a light, white mass in which one can almost distinguish the shiny starch grains. If it is pounded with a masher the starch particles are crowded together so that they catch the light less and look darker in color. Adding milk or butter tends to make the mixture more yellow than the plain potato, but the more it is beaten—that is, the more air is forced in between the particles—the whiter and more creamy it becomes.

In this country the chief test of excellence is mealiness, which means that when cooked potato shall form a crystallinelike mass with almost distinct starch particles. This quality depends largely on the proportion of starch present. If it is abundant and evenly distributed throughout the tuber the cells burst open in cooking and a light, flaky, uniform mass results. If the proportion of starch is small in any part of the potato, water or juice is likely to replace it, which will make the potato soggy when cooked. As has been stated, fresh, mature tubers hold more starch than either young or long-stored ones, and the inner medullary layer or core is more likely to be poor in starch than the outer layer. Therefore, well-developed and well-ripened tubers are more likely to be mealy when cooked than are the new or watery tubers or those which have a large core with many long arms branching into the outer parts of the tuber (see p. 4).

This, however, does not tell the whole story. Anyone who cares for early potatoes knows that there is a quality between sogginess and mealiness that is commonly described as “waxiness,” and in many parts of Europe this is preferred to mealiness. While mealiness depends on abundant starch and sogginess on a large water content, waxiness, which to some extent at least is a varietal characteristic, is attribut-

¹ U. S. Dept. Agr., Farmers' Bul. 256 (1906).

able to a large proportion of protein to starch. If the protein is sufficiently abundant it will harden in cooking to form a sort of waxy framework in which the starch will be lightly held together instead of separating into distinct flakes as in mealy potatoes, in which there is not enough protein present to resist the pressure of the starch. Such waxy potatoes retain their shape better than the mealy ones and are more suitable for garnishing meats, for salad making, and for the preparation of many fancy dishes. As has been shown, the proportion of protein to starch is greater in young than in mature tubers, and therefore, in American potatoes at least, the early varieties are most likely to have this waxiness. In point of flavor there is almost as much difference as in consistency; the nitrogenous tubers usually contain a larger proportion of acids, and perhaps also of sugars and solanin (see p. 13), than do the starchy ones.

POTATO PRODUCTS.

STARCH.

The chief article manufactured from potatoes is starch, which is used for laundry purposes, for sizing paper and textiles, and for other technical purposes; it also finds many uses in cookery, though not so generally now as before cornstarch became common. One of the good qualities of potato starch is that a relatively short time is required to cook it thoroughly, and so gravies, etc., can be quickly made with it and yet not have a raw taste.

Potato starch is sometimes marketed under the trade name of potato flour, particularly that of foreign make. The term is also applied to a different kind of product fairly well known in some European countries, which is made by grinding dried potatoes. Such a product is also called potato meal, which is perhaps a more distinctive name for it. A somewhat similar preparation is known as potato flakes. Both of these are much used in certain parts of Europe in bread making, particularly when wheat flour is scarce. Plain boiled and mashed potato may be used for the same purpose. The best results are obtained when not more than one-third of the flour is replaced by potato meal or flakes. The recipes commonly call for not more than one part of the latter to three parts of flour. Such potato bread is more moist than ordinary wheat or rye bread, the potato starch holding more water than that from the cereals. Similar mixtures of potato and flour are often used for pancakes, batter cakes, etc., and sometimes a kind of batter cake or similar dish is made from potato without flour. Many cooks think that ordinary wheat bread and rolls are lighter if the yeast is started with potato before the flour is mixed in, which would indicate that the potato supplies the yeast with better food for its growth than does the flour.

DRIED OR EVAPORATED POTATOES AND CANNED POTATOES.

Potatoes are so valuable in the diet that many attempts have been made to put them into a compact form in which they can be kept for a long time. This is usually accomplished by drying, which preserves them from decay and reduces their bulk. One of the oldest of such preparations is that long used in Peru and known as "chunno," made by freezing, thawing, and drying, which reduces the potatoes to about one-fourth of their original weight. There are a number of evaporated or dried-potato preparations in American and European markets, and although the method of preparation differs considerably in the various brands, the main principle is the same, namely, driving off water and so preventing decay. The changes which we call decay are caused mainly by the development of bacteria, molds, and yeast. These can grow and reproduce only where there are favorable conditions, of which the necessary ones are suitable food, moisture, and warmth. Therefore, if the moisture is removed, their growth is prevented or retarded. The fact that the bulk and weight of the potatoes is reduced at the same time is an advantage, because dried or evaporated foods are often useful for camping expeditions and under other conditions where fresh potatoes can not be easily procured, storage space is at a premium, or transportation is difficult. The chemical composition of such desiccated or evaporated potatoes is practically that of the original tubers minus almost all the water. (See Table I, p. 5.) Of course, if extreme heat is used in the preparation, part of the starch may be changed to dextrin, and there may be other minor changes in the chemical composition. There is no reason to suppose that drying involves a loss of nutritive material. Its influence on such substances as vitamins (see p. 7) is not definitely known.

The water content of various kinds of desiccated potatoes has been found to range from 4.8 to 7.9 per cent and their total carbohydrates from 77.9 to 80.6 per cent, showing their general composition to be not very different from that of good white flour. Desiccated potatoes are usually soaked in water before using, and the water which they take up then and during cooking brings back their water content to about that of ordinary potatoes. Their flavor and general characteristics, however, are not quite those of good fresh potatoes.

The canned potatoes found on the market are prepared for use in camps or wherever it is not convenient to cook food. In composition such goods do not differ much from similar potatoes freshly cooked.

STORAGE—ITS EFFECT ON QUALITY.

It is a fact of common experience that potatoes suffer more or less change during storage, and this is a matter of importance from the standpoint of household costs as well as of the table quantity of

this important vegetable. If the tubers were originally affected with rots these will go on developing until the potatoes are quite unfit for food. If the skin, which is the natural protection of the tuber against the minute forms of life which cause decay, has been broken or bruised, the injured portion offers an entrance to bacteria, etc., which will develop in them, especially if the potatoes are stored in a warm, moist place. Aside from these abnormal changes there are others which occur under the best of conditions. The potato, it must be remembered, is not a dead thing, but one from which active plant life will be renewed as soon as conditions are favorable. Even during the latent winter period the protoplasm of the cells is constantly producing minute changes known as "after ripening," in which part of the sugar is broken down and carbonic acid and water are given off. Part of the insoluble starch is also changed into dextrin and other soluble forms. This is believed to be due to the action of ferments normally present, which aid the plant by thus changing its stored food into a form which can be used for new growth. The extent of these changes seems to depend ordinarily on the age of the tuber and the temperature at which it is kept. Everyone knows that potatoes stored where it is warm sprout more readily than those kept in a cold cellar. The older the tuber is, the more ready it will be to begin its new growth and the more abundantly will the starch be converted into sugars. This explains why old potatoes are less starchy and mealy and sometimes sweeter than fresh ones. The temperature especially affects the rapidity of new growth. This is one reason why potatoes stored in a warm place are more likely to shrink than those in a cool place. These facts also suggest why frozen potatoes have a sweet taste; the change of starch into sugar by the enzymes goes on regardless of the cold, but the activity of the cell protoplasm is checked by the cold and the sugar accumulates instead of being broken down. The sweet taste is more noticeable in tubers which have been slowly frozen than in those subjected to a sudden cold, because the sugar has had a longer opportunity to form. If frozen potatoes are left for a few days in a moderate temperature part of the sugar will revert to starch, and the sweet taste will in a measure disappear. Of course, the amount of material which is changed during storage will vary with the conditions, but sound potatoes properly stored should not shrink more than 10 or 12 per cent. The most favorable temperature for keeping potatoes is from 32° to 50° F., and if the store-room is dry, well aired, and partly lighted, they are less likely to be attacked by disease or harmful bacteria.

Solanin, an acrid poisonous substance, which is characteristic of the nightshade family, develops in unusual quantities in sprouting potatoes and in those which have turned green from exposure to the light. A trace of it (0.01 per cent) is present in ordinary potatoes

and is said to be what gives them their characteristic flavor. Such very small quantities are not harmful, and for that matter the amount which develops in sprouting or green tubers is not usually dangerous; but since the flavor is very often bad, it is a good rule to avoid green tubers or to cut out any green sections before cooking them.

The illness (often serious and sometimes fatal) attributed to green tubers, which occasionally results after eating cooked potato salad, for instance, is due, not to solanin or any other such substance, but to the rapid growth in the digestive tract of harmful bacteria (usually of the group called fecal bacteria) accidentally present on the potato or some food served with it and conveyed to the food most often by the unclean hands of some one who has handled, cooked, or served it.

SELECTION OF POTATOES FOR TABLE USE.

Appearance, taste, and consistency are the points by which we judge a cooked potato. Unfortunately, it is not always easy to tell from the appearance of raw potatoes which will prove the best, but there are certain marks which aid in making a choice.

Young or new potatoes are preferable to old or stored ones. Such tubers usually have a smoother skin, though they are not as mealy and do not keep as well as the older ones. Very large potatoes are not especially desirable, partly because it is hard to cook them evenly and partly because they are often very variable in texture. Smooth, regularly shaped tubers with comparatively few eyes are more economical than irregular ones which can not be pared without considerable waste.

Different varieties may have distinct flavors, but the soil and climate in which they are grown and the fertilizers used cause such great differences in flavor that variety alone is no sure guide. The freshly gathered mature tubers usually contain a large proportion of mineral matters and acids, and therefore have the better flavor. Tubers old enough to sprout begin to develop an acrid taste, probably due in part to an increased solanin content.

Very watery potatoes are always undesirable, because they become soggy in cooking. Young tubers are more juicy than mature ones, but their juice often holds so much more protein in solution that they cook to the well-known waxy consistency. A good potato to be mealy when cooked should feel firm when pressed in the hand. If cut, it should separate crisply under the knife and be of even density throughout. If the core is large and soft, it will make a soggy mass full of holes in the center.

In choosing potatoes, weight and size should be taken into account. As a rule, the smaller the individual potatoes the greater the weight of a bushel. The legal weight of potatoes in most States is 60 pounds¹ to the bushel, or 15 pounds to the peck, and three or four potatoes of average size weigh a pound. Hence, one may reckon 45 to 60 medium-sized potatoes to the peck. The time required for cooking, of course, depends upon the size of the potatoes, smaller ones needing less heat than larger ones. For this reason those of uniform size are usually to be preferred to large and small ones mixed. If a lot is not uniform, it is often worth while to sort them and use the large ones with roast meats, or at other times when the oven need not be especially heated, and save the small ones for occasions when quick cooking is more convenient. When the potatoes are very large, or time is pressing, it is often desirable to increase the surface exposed to the heat by cutting them in pieces before cooking, in spite of the fact that this slightly increases the amount of nutrients lost. If they are pared and cut into small cubes or thin slices, they will cook very quickly and may then be creamed, mashed, or served in other ways.

FOOD VALUE OF POTATOES.

Potatoes are an important food in so many countries that much experimenting has been done to test their nutritive value by scientific methods, and the work fully bears out practical experience in proving that they are wholesome and well digested. Many experiments show that almost all of the carbohydrates and about four-fifths of the protein which potatoes supply are actually utilized by the normal body.

There is practically no reliable evidence as to the favorable effect of cooking on the digestibility of potatoes, but what little there is suggests that the different methods have less influence than is sometimes supposed. It seems probable that well-cooked, mealy potatoes in which the starch grains are thoroughly broken open offer less resistance to the action of the digestive juices than ill-cooked, soggy ones in which the flesh is only partially broken down and which enter the alimentary tract in lumps. It is doubtful, however, if the differences are great enough to be of importance in the ordinary diet.

When potatoes are selling at a dollar a bushel 10 cents spent for them will buy about 6 pounds of tubers. The same sum spent for wheat bread at 5 cents a pound loaf will purchase only 2 pounds of material. At first glance it might seem that potatoes are much cheaper than bread, but they contain so much more refuse and water

¹ In two States, namely, North Carolina and Virginia, the legal weight of a bushel of potatoes is 56 pounds.

than the bread that the 6 pounds of potatoes furnish decidedly less protein and fat and slightly less carbohydrates than the 2 pounds of bread. It is easy, therefore, to see why, in spite of their cheapness and similar composition, they should not occupy the same place in the diet as bread. A diet of bread alone would be rather too one-sided for the best development of bodily powers, but would come nearer to supplying the required protein without excess of carbohydrates than potatoes alone.

With respect to the total nutritive material they supply, raw potatoes resemble fresh fruits, such as bananas and apples, with their seven or eight parts of water to one of food substance, more than they do such foods as uncooked flour or rice, with their one part of water to nine of nutritive material. Since raw potatoes consist of only one-fifth and raw rice, for instance, of seven-eighths nutritive material, one would naturally say that rice is more than four times as nutritious as potatoes, and this is true of them as they are bought in the market. This, however, is not the case when they are compared in the state in which they appear on the table. When rice is cooked water is added to it, with the result that when it is eaten it is not very different in composition from cooked potatoes; thus a pound of boiled rice and a pound of mashed potatoes would have very much the same total fuel value, a fact which has been intuitively recognized by housekeepers, who often use them interchangeably to serve with meats, etc. They do not, however, have the same effect on the alkalinity of body tissues and fluids.

According to generally accepted standards, a man at moderately active work requires about one-fourth pound of protein a day, along with sufficient fats and carbohydrates to give the total food an energy value of about 3,500 calories. It would take about 9 pounds of potatoes to furnish this energy, but that quantity would yield much less protein than the amount called for by the standard. About 19 pounds of potatoes would be needed to yield the required 0.25 pound of available protein, an obviously impossible bulk for a day's ration. Except under stress of necessity, however, few persons try to live entirely or even principally on potatoes. Ordinarily they are eaten with other foods rich in protein, such as meat, milk, eggs, etc., and thus they supplement these nitrogenous foods by furnishing the needed carbohydrates in an easily digested form.

The abundant mineral matters which they contain also supply the body with important building materials and help to regulate its processes. As is the case with most vegetables and fruits, potatoes, when they have been digested and assimilated by the body, tend to make the tissues and fluids of the body more alkaline. Meats and eggs, on the other hand, tend to make them more acid, while the cereals (including rice) do not affect them greatly either way. Physiolo-

gists therefore speak of different food materials as being potentially alkaline, acid, or neutral. The body performs its work best when its condition is either neutral or slightly alkaline, and consequently, in the ordinary mixed diet, it is important to counteract the effect of the potentially acid foods like meats, eggs, and fish with potentially alkaline ones like vegetables and fruits. It has been estimated that a portion of potatoes large enough to supply the body with 200 calories of energy (over half a pound) would counteract the acidity from a portion of meat yielding 100 calories (about $1\frac{2}{3}$ ounces). These conclusions are in accord with the old custom in families where living is simple of serving a goodly helping of potatoes and other vegetables in proportion to the helping of meat.

Aside from these considerations, potatoes deserve their important place in the diet for other reasons. They are easy to cook and can be prepared in so many ways that they add variety to the list of vegetable dishes, especially in winter, when green vegetables are not common. They have a mild, agreeable flavor acceptable to almost everyone and combining well with other foods, but not sufficiently pronounced to become tiresome. Owing to the ease with which they are grown and their abundant yield, they are usually a relatively cheap food. Considering all these advantages, it is not surprising that in the temperate regions of America and Europe they rank next to the breadstuffs as a source of carbohydrates in the diet.

SWEET POTATOES.

The plants known in the United States as sweet potatoes are called by botanists *Ipomoea batatas* or *Batatas edulis*, and are probably natives of tropical America. They were introduced into Europe earlier than the white potato and were formerly so commonly grown in the warmer countries of Europe that when the white potato supplanted them the latter took its English name from a corruption of the usual European name of sweet potato—batatas. Since then, however, they have fallen out of use in Europe, it is said because they are considered too sweet for vegetables and not sweet enough to take the place of cakes, sweet fruits, etc.

At present the sweet potato is grown throughout the Tropics and warmer temperate zones, being a well-known food crop in the southern part of North America, in Central America, and in the West Indies, Hawaii, and the Philippines. In the southern United States they play almost as important a rôle as white potatoes do in other parts of the country and have almost usurped the name potato. Although the name yam (see p. 23) belongs rightly to an entirely different tuber hardly known outside the Tropics, sweet potatoes are sometimes so called in the United States, particularly certain

of the sweeter and more juicy kinds quite generally preferred in the South, as distinguished from the dry, starchy varieties which are preferred in northern markets.

The edible portion of the sweet potato is not a tuber like the white potato, but a true root. Its internal structure is more uniform than that of the white-potato tuber, but its rôle in the life history of the plant is much the same, that is, to act as a storehouse of plant food for the growth and early development of a new crop of plants. Above ground the plant is a vine which occasionally produces flowers (and in warm countries seeds) resembling somewhat those of its relatives, the morning-glories. The first touch of frost is fatal to the vines of most varieties, so the cultivation is limited to warm countries where the plants are perennials and the growth is practically continuous, or to regions where the summer is long enough to insure the ripening of a crop. Some of the earlier maturing sorts are extensively grown as far north as New Jersey.

The color of the sweet-potato skin ranges from light tan to dark brown, or red and purplish tones, and the flesh from almost white or pale lemon yellow to a deep reddish orange. The medium and lighter shades are most frequently seen in the northern markets. The weight of the roots also varies considerably, but those which are of medium size and of regular shape are to be preferred for the table.

Although the bulk of the sweet-potato crop is used for human food, some of the coarser kinds are fed to stock, and a small part is used for the manufacture of starch.

COMPOSITION AND NUTRITIVE VALUE.

In general chemical composition the sweet-potato root resembles the tuber of the white potato, although there are important differences between them. The average composition of sweet potatoes raw and cooked is given in Table II, together with similar figures for the white potato.

TABLE II.—Average composition of sweet and white potatoes.

| Kind of potato. | Ref-
use. | Water. | Pro-
tein. | Fat. | Carbohydrates. | | Ash. | Fuel
value per
pound. |
|--|----------------|----------------|----------------|----------------|---------------------------|-----------------|----------------|-----------------------------|
| | | | | | Sugar,
starch,
etc. | Crude
fiber. | | |
| | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Calories.</i> |
| Sweet potato (edible portion)..... | | 69.0 | 1.8 | 0.7 | 26.1 | 1.3 | 1.1 | 560 |
| Sweet potato (as purchased)..... | 20.0 | 55.2 | 1.4 | .6 | 21.9 | | .9 | 450 |
| Sweet potato (cooked)..... | | 51.9 | 3.0 | 2.1 | 42.1 | | .9 | 905 |
| Sweet potato (canned)..... | | 55.2 | 1.9 | .4 | 40.6 | .8 | 1.1 | 800 |
| White potato for comparison (edi-
ble portion)..... | | 78.3 | 2.2 | .1 | 18.0 | .4 | 1.0 | 375 |
| White potato for comparison (as
purchased)..... | 20.0 | 62.6 | 1.8 | .1 | 14.7 | | .8 | 305 |

The proportion of total sweet potato discarded with the skin as refuse is probably about the same as in white potatoes, 20 per cent. The most noticeable differences between white and sweet potatoes are in the carbohydrates and water. Sweet potatoes contain on an average about 9 per cent less water and 9 per cent more carbohydrates than white potatoes. They also contain as little, or even less, protein; but the proportion of available protein is higher than in white potatoes, being about 1.3 per cent. This advantage, however, is hardly large enough to be of consequence, nor is the fact that they contain a trifle more fat.

More important than any of these differences is that in the nature of the carbohydrates. Sweet potatoes contain a slightly larger proportion of crude fiber than white, though the amount is no higher than in most vegetables. As would be guessed from their flavor, they contain considerable quantities of sugar, part of which is cane sugar and part invert sugar or glucose. The proportion of sugar and starch varies with the climate. The warmer the place in which the plant is grown, the greater the proportion of food laid by in the form of sugar. Tropical sweet potatoes sometimes contain almost equal quantities of sugars and starch. Those grown in New Jersey, on the other hand, probably do not average more than 5 or 6 per cent of sugar, or about one-fifth of their total carbohydrates.

After harvesting, sweet potatoes are put through a curing process during which they lose moisture. Sweet-potato marketing and storage are of special interest to the grower and shipper. The housekeeper who wishes detailed information on the subject will find it in earlier publications of the department,¹ as such questions have received careful study by the department specialists.

With respect to the storage of sweet potatoes in the home for family use, it seems to be generally conceded that the best results are obtained when the roots are kept in a dry, well-ventilated place, at a moderately warm rather than a cold temperature. This would mean that they should be stored in the pantry or some similar place rather than in the cellar. In handling potatoes in the home care should be taken not to bruise them, as when thus injured they are likely to spoil.

Little is accurately known about the chemical changes which take place during storage. The chief one, however, is that of starch into sugar. The most recent investigations indicate that after sweet potatoes are first harvested there occurs a rapid transformation of starch into cane sugar and reducing sugars, which is initially due to internal rather than external causes. The somewhat slower and more regular change which takes place during ordinary storage from

¹ U. S. Dept. Agr., Farmers' Buls. 324; 548.

starch to sugar seems to be associated in a general way with seasonal changes in temperature. In sweet potatoes kept in cold storage (4° C.) there is a rapid disappearance of the starch and an accompanying increase in cane sugar. It is a matter of common experience that late in the season sweet potatoes are apt to deteriorate in quality and sometimes develop a disagreeable taste, especially if they have been left in a cold place. The peculiar and characteristic flavor often noted is due to a fungus disease resembling dry rot. These undesirable changes may take place at any temperature below 50° F. To lessen the danger of shipping in cold weather, the southern sweet-potato crop is usually sent north early in the autumn and stored near the retail market.

In choosing sweet potatoes at the market, firm, fresh-looking ones should, of course, be preferred to the old and shriveled roots, and medium-sized, regular-shaped roots are more satisfactory than very large, very small, or irregular ones, for they cook more evenly, give less waste in paring, and are of better size to serve. Early in the season unripe sweet potatoes are sometimes marketed and may be recognized by cutting them; the flesh will soon turn dark green, whereas in the properly ripened roots it will not change color.

COOKING.

The changes which cooking makes in sweet potatoes are, in general, similar to those in white potatoes. One special point is generally noticeable—the longer the cooking is continued, the more moist does the root become. This is probably because part of the starch is made soluble by the heat and then dissolved in the juice, while the cane sugar is split up into simpler sugar. The very sweet southern varieties become so moist during baking that a sirup frequently oozes through the skin.

There are many different ways of preparing sweet potatoes for the table, the most common being simply boiling or baking. They are also fried, cooked with sugar and butter (when they are commonly called “candied”), used in making pies, like pumpkin or squash, or in other made dishes.

DRIED AND CANNED SWEET POTATOES.

Dried sweet potatoes were formerly prepared at home, and strings of them were hung from the rafters along with apples and other drying fruits and vegetables, but in these days of storage warehouses the custom has very largely passed away. Special devices for evaporating sweet potatoes are on the market, and desiccated sweet potatoes prepared in much the same way as desiccated white potatoes are

sold to some extent.¹ Sweet potatoes cut into small cubes and roasted or parched until brown are used like parched corn as a homemade substitute for coffee.

Within recent years the practice of canning sweet potatoes has been developed with so much success that it is now an important industry. Medium-sized roots are preferred for canning and are usually put up in 3-pound tins. They are used like other canned vegetables when it is not convenient to depend upon a fresh supply. Canned sweet potatoes have been used in the Army ration in the Philippines and are said to be in demand for lumber and mining camps.

Very rarely a flour is made from sweet potatoes. Like that from white potatoes, it is prepared by slicing, drying, and grinding the root.

DIGESTIBILITY AND PLACE IN THE DIET.

Not many special experiments have been made to test the digestibility of sweet potatoes, but what little work has been done indicates a degree of digestibility equal to that of white potatoes. The protein may be slightly less digestible, but the difference is too slight to be of practical importance.

It is a matter of common experience that sweet potatoes are wholesome, and they are ordinarily digested without distress. Many persons find the starchy varieties so dry that they do not relish them without large quantities of butter. This makes a rather rich mixture and is perhaps accountable for the digestive disturbances occasionally experienced.

Considering both composition and digestibility, it may be said that the nutritive value of sweet potatoes is much the same as that of white potatoes and that they are well fitted to occupy the same place in the diet and furnish a palatable substitute for white potatoes. Their characteristic and pleasing flavor has the advantage of giving variety to the diet. In the North they frequently cost somewhat more than white potatoes, but are still among the cheaper vegetables. In the South they are usually cheaper than white potatoes and merit their extensive use.

THE JERUSALEM ARTICHOKE.

The Jerusalem artichoke (Jerusalem being a corruption of *girasole*, the Italian name for sunflower) is a tuber-bearing member of the sunflower family and is entirely distinct from the French or true artichoke, sometimes called globe artichoke. Like the sunflower, the Jerusalem artichoke is of American origin and was an important

¹ South Carolina Sta. Bul. 71 (1903), p. 6; U. S. Dept. Agr. Farmers' Bul. 169 (1903), p. 25.

food of the Indian before America was discovered. Many farmers in this country are prejudiced against the Jerusalem artichoke because it spreads so rapidly and becomes a weed; but in Europe, and to a certain extent in the United States, it is considered a valuable plant, since the forage may be fed to stock, and the abundant tubers are useful as a vegetable and also for feeding farm animals. The bright-yellow flowers at the top of the tall stalks no doubt help to make the plant welcome. It is often allowed to grow on the edge of a garden or some similar place, and the tubers are dug for home use. They are also fairly common in market in certain localities. In flavor the tubers slightly resemble the true artichoke, which doubtless accounts for their name. They contain on an average 78.7 per cent water, 2.5 per cent protein, 0.2 per cent fat, 17.5 per cent total carbohydrates, of which 0.8 per cent is crude fiber, and 1.1 per cent ash. Judged by these figures the artichoke tubers are quite similar in general composition to potatoes (see p. 5). They differ very markedly, however, in respect to the nature of the carbohydrates present, inulin and levulin (which are chemically closely related to starch), and a considerable amount of pectose bodies replacing the starch which is characteristic of potatoes. Little is known regarding the digestibility of the typical carbohydrates which these tubers contain, but recent investigation indicates that they do not differ materially from starch in this respect. Jerusalem artichokes used in various ways as a vegetable give a pleasant and wholesome variety to the diet, particularly as they are not injured by frost and may be dug in the early spring when fresh vegetables are not very common. As the plant is very prolific and easily grown, the Jerusalem artichoke is not an expensive vegetable. The tubers may be boiled or steamed like turnips, creamed or fried like parsnips, or used for making soups and in other similar ways. An old-fashioned way of serving them is to slice the raw root, cover with vinegar, and serve as a relish.

SOME TROPICAL STARCH-BEARING ROOTS.

In the Tropics a very large proportion of the carbohydrates of the diet of both native and European residents is furnished by starch-bearing roots, such as the cassava, yam, dasheen, yautia, and taro. Mention may be made also of stachys (a curiously ribbed Japanese tuber long known in the United States, but chiefly as a dietary curiosity). Most of these roots are not common vegetables in the United States, though some or all are sold in the oriental quarters of our cities and sometimes in a limited way in other markets, and the cassava and dasheen are grown in the Southern States. In Porto Rico and our other island dependencies, such starch-bearing roots are very

important articles of diet, and as they may be readily shipped in good condition and are known to be palatable and wholesome, it seems not unlikely that they may become important additions to the list of starchy vegetables commonly used in the United States. Most of them have two distinct uses in the diet; that is, they are used much like bread, as a common source of carbohydrate food, and, like succulent vegetables, as accompaniments of meat or other dishes.

CASSAVA.

The cassava is an American plant widely used for food purposes throughout Central America, the West Indies, and the hot regions of South America, and now cultivated to a considerable extent in Florida, but as a cheap source of commercial starch, glucose, etc., and as a cattle food, rather than as a vegetable. There appear to be two principal varieties, the sweet cassava and the bitter cassava (which is poisonous unless specially prepared, owing to the prussic-acid compound present), but only the sweet is cultivated in the United States. Both varieties (but the bitter only after proper treatment) are eaten as a vegetable, boiled, baked, fried, or cooked in other ways, and by drying and grinding are made into a flour which forms the basis of various sorts of bread and biscuits. Thin, crisp cassava cakes are not uncommonly sold in the United States under a variety of trade names.

Judged by the figures given in Table III, page 27, the cassava is as rich in starch as the potato, and like it can be classed as a succulent carbohydrate food. The amount of protein and fat present is very small, while the mineral matters are not remarkable in any way. The culture and uses of cassava and related matters have been discussed in a previous publication¹ of this department.

Cassava starch in the form of tapioca is produced in large quantities in the Tropics from the bitter cassava and is prized as a palatable and valuable food starch. It is a common article of commerce much used for making puddings and other dishes.

YAMS.

True yams, sometimes confused in name with sweet potatoes, belong to a group of tropical and semitropical climbing plants cultivated in a number of varieties and producing edible starch-yielding roots. All of the edible species are of Old World origin. These vary greatly in size, some being no larger than potatoes and others several feet in length and weighing 30 or more pounds. Yams are known in only a limited way in the United States, but are common and important

¹ U. S. Dept. Agr., Farmers' Bul. 167 (1903), pp. 32.

foods in Porto Rico, Hawaii, and the Philippines, ranking in Porto Rico, for instance, next to the sweet potato in importance.

In appearance tubers of comparable size look much like sweet potatoes, while in flavor and in composition yams very closely resemble potatoes. (See p. 27.) They have not, however, the keeping qualities of sweet potatoes, and in countries where they grow are usually left in the ground until required for use. Experience and experiment alike show that yams can be readily prepared in acceptable ways and are to be regarded as an important carbohydrate food in regions where they are available. They are prepared for the table in much the same way as potatoes and sweet potatoes.

Starch is made from the yam and also a flour used in tropical countries as a breadstuff. Like the flours and starches prepared from other edible roots, these yam products are not used alone for making yeast-raised bread, since they do not contain the gluten which is characteristic of wheat flour and which gives the light, porous texture to wheat bread. According to experimental evidence, 96 per cent of the carbohydrates present in yams is assimilated on an average.

DASHEEN, TARO, AND YAUTIA.

Dasheen, taro, and yautia are closely related botanically and are so much alike in general character and the uses to which they are put that they may be grouped together for discussion. They belong botanically to the Arum family, which includes also the large-leaved ornamental plant called Caladium or "elephant's ear," frequently seen in gardens, as well as the calla lily and the Indian turnip or jack-in-the-pulpit. Another member of the Arum family worthy of mention is the tuckahoe or Virginia wake-robin (*Pentandra virginica*), which is closely allied to the tropical America yautia. The tuckahoe grows in marshy bottoms and river banks. Its roots, like those of the yautia and Indian turnip, are very acrid when raw and are full of needles of oxalate of lime, but when cooked are of a very good flavor and much like the other aroid roots. The American Indians are said to have made a kind of bread of the tuckahoe, and, as the earlier records show, tuckahoe was of considerable importance to the pioneer settlers of the United States.

The dasheen, taro, and yautia all form large underground rootstocks or corms, in which starch is stored, and they are important food plants in many tropical and subtropical countries. Taro is an important crop in Hawaii and, indeed throughout Polynesia, and from it the Hawaiians make the cooked and slightly fermented paste called poi, a characteristic and very important article of their diet. Taro, dasheen, and especially perhaps yautia, are common in Porto Rico, and it was largely through the experiment

station there that agriculturists in this country became interested in them. They grow well in wet lands and make a profitable root crop in soils too moist for potatoes or sweet potatoes, while the dasheen also has proved itself well adapted for other soil conditions. For this reason the Department of Agriculture and some of the experiment stations of the South Atlantic and Gulf States have been experimenting with them recently in the hope of developing a profitable crop for the moist, rich soils of those coast-plain areas. Particularly good results have been obtained with the dasheen.¹ The Department of Agriculture has done much to make it known in the United States, and it is quite generally liked by those who have tried it. Though particularly useful in warm localities, where white potatoes do not grow well, it can also be marketed elsewhere, for it has good shipping and keeping qualities, and while it is not expected to replace the potato crop it may well supplement it to add variety to the list of starchy vegetables.

The dasheen root consists of a large stocky central rootstock or corm, from which cormels or tubers branch out on all sides. The central corm is nearly spherical, but slightly pointed toward the top, and sometimes weighs as much as 6 pounds. It is firmer in texture than the tubers which branch off from it.

Both corms and tubers are edible, though in some varieties the tubers have a finer, more succulent flesh and a milder flavor. In general their texture may be said to resemble that of white potatoes. The flavor of dasheen is very much like that of the potato, being starchy and mild, and has little if any of the characteristic acid taste which is common to nearly all the uncooked roots of this family of plants but which is removed by cooking. The color of the roots varies according to the variety, some being white or cream color, while others run into orange, brown, or lavender, or even show a marbled effect. The starch grains are very much smaller than those of potatoes and most other common starchy food materials. The roots also contain a gummy substance which sometimes interferes with extracting the pure starch if ordinary methods are used. These points, however, are more important in connection with starch manufacture than with the value of these roots as human food.

Recipes for cooking dasheen have appeared in earlier publications of this department.² Their composition, as given in the table on page 27, shows that, like the other starchy roots described in this bulletin, their nutritive value depends on carbohydrates and mineral matter rather than on protein and fat.

¹ U. S. Dept. Agr., Bur. Plant Indus. Bul. 164 (1910); U. S. Dept. Agr., Bur. Plant Indus. Doc. 1110 (1914), pp. 11.

² U. S. Dept. Agr., Bur. Plant Indus. 1110 (1914), p. 11.

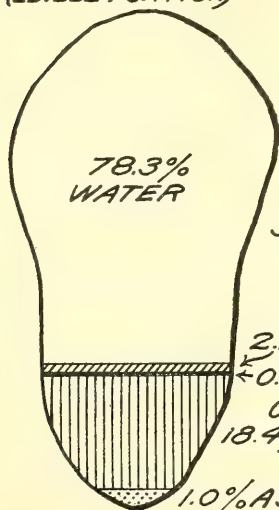
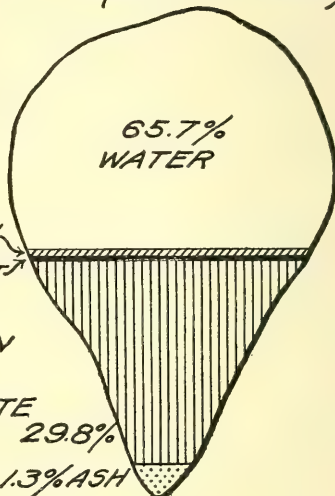
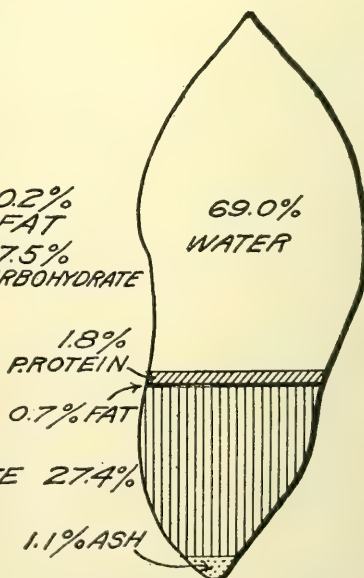
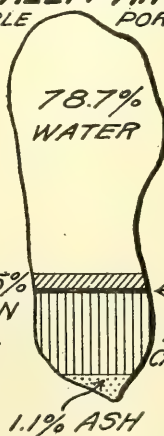
POTATO
(EDIBLE PORTION)**DASHEEN**
(EDIBLE PORTION)**JERUSALEM ARTICHOKE**
(EDIBLE PORTION)**CASSAVA**
(EDIBLE PORTION)**SWEET POTATO**
(EDIBLE PORTION)

FIG. 6.—Composition of common starchy root vegetables. These outline figures show diagrammatically the proportion of nutrients present. Plain white indicates water and the differently shaded portions protein, fat, carbohydrates, and ash, respectively.

COMPOSITION AND ENERGY VALUE OF TROPICAL STARCHY ROOTS AS COMPARED WITH POTATOES AND SWEET POTATOES.

Table III shows the composition of the tropical starchy roots as compared with potatoes and sweet potatoes.

TABLE III.—Average composition of edible portion of dasheen and other tropical starch-bearing roots.

| Kind of food. | Water. | Protein. | Fat. | Total carbohy-
drates. | | Ash. | Fuel
value per
pound. |
|------------------------------------|----------------|----------------|----------------|---------------------------|-----------------|----------------|-----------------------------|
| | | | | Sugar,
starch,
etc. | Crude
fiber. | | |
| | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Per ct.</i> | <i>Calories.</i> |
| Sweet cassava..... | 66.0 | 1.1 | 0.2 | 30.2 | 1.8 | 0.7 | 610 |
| Cassava starch..... | 10.5 | .5 | .1 | 88.8 | | .1 | 1,625 |
| Cassava bread..... | 10.5 | 9.1 | .3 | 79.0 | | 1.1 | 1,610 |
| Cassava cakes or wafers..... | 10.3 | 1.1 | .2 | 85.2 | 1.6 | 1.6 | 1,605 |
| Yams..... | 72.9 | 1.8 | .2 | 23.3 | .6 | .9 | 475 |
| Dasheen..... | 65.7 | 3.0 | .2 | 28.8 | .7 | 1.3 | 605 |
| Taro..... | 70.9 | 1.8 | .2 | 23.2 | .8 | 1.2 | 475 |
| Yautia..... | 70.0 | 2.2 | .2 | 26.1 | .6 | .9 | 530 |
| Potatoes for comparison..... | 78.3 | 2.2 | .1 | 18.0 | .4 | 1.0 | 380 |
| Sweet potatoes for comparison..... | 69.0 | 1.8 | .7 | 26.1 | 1.3 | 1.1 | 560 |

The preceding diagram (fig. 6) shows in graphic form the composition of sweet potatoes, Irish potatoes, and other starchy roots, and perhaps makes clearer data such as are recorded in the table.

It is apparent from the diagram that these typical starchy roots are very similar in general composition. Degree of ripeness, length of storage, and other factors influence water content considerably. Individual specimens of any one of them would vary more or less in water content, but on the average water makes up about two-thirds to three-fourths of the total, while carbohydrates constitute the greater part of the nutritive material. These vary in the different groups, starch being the characteristic carbohydrate of potatoes, cassava, and dasheen; sugar and starch of sweet potatoes; and inulin, levulin, and pectose bodies of Jerusalem artichokes. The proportion of protein in these roots is small, but valuable in nutrition, in part because of the vitamins believed to accompany the nitrogenous material. The proportion of ash is actually small, though relatively large as compared with other foods. As a group, starchy roots are a



FIG. 7.—Energy value of some common starchy vegetables.

wholesome, palatable, and useful food, and can be prepared for the table in many acceptable forms without undue labor or fuel.

The starchy roots are important in nutrition as sources of energy. Figure 7 shows in graphic form the energy value of some of the more common of such vegetables.

As the diagram shows, the energy value varies from about 400 to 600 calories per pound. In general, the drier the root the higher the energy value, which means that potatoes, for instance, which have been harvested and dried out may have an energy value considerably higher than the value here cited as an average.

CONCLUSION.

All these starchy tubers and roots—potato, sweet potato, Jerusalem artichoke, cassava, yam, dasheen, yautia, and taro—yield the body little protein to supply nitrogen needed for building body tissue and little energy-producing fat, but on the other hand their fine-grained starch and other carbohydrates supply easily digested energy-yielding nutritive material and small quantities of valuable mineral matters which help to build the bones and are useful for other physiological purposes. Thanks to the ease with which most of them are cultivated, they are among the cheaper of our vegetables, while their usually mild flavors and the variety of ways in which they may be prepared make it possible to serve them in many combinations. They merit their extensive use because they make healthful supplements to other classes of food found in the usual mixed diet, and because they are economical and agreeable sources of body energy.

PUBLICATIONS OF THE DEPARTMENT OF AGRICULTURE OF INTEREST IN CONNECTION WITH THIS BULLETIN.

- Yearbook 1900, The value of potatoes as food.
Farmers' Bul. 142, Principles of nutrition and nutritive value of food.
Farmers' Bul. 167, Cassava.
Farmers' Bul. 256, Preparation of vegetables for the table.
Farmers' Bul. 295, Potatoes and other root crops used as food.
Farmers' Bul. 324, Sweet potatoes.
Farmers' Bul. 375, Care of food in the home.
Farmers' Bul. 548, Storing and marketing sweet potatoes.
Bur. Chem. Bul. 106, Cassava: Its content of hydrocyanic acid and starch and other properties.
Bur. Plant Indus. Bul. 164, Promising root crops for the South.
Bur. Plant Indus. Doc. 1110, The dasheen, a root crop for the South.
Bur. Plant Indus. Office Foreign Seed and Plant Introduction, Recipes for the dasheen.
Office Expt. Stas. Bul. 43, Losses in boiling vegetables, and the composition and digestibility of potatoes and eggs.

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A. C. TRUE, Director



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PROFESSIONAL PAPER

December 15, 1916

FATS AND THEIR ECONOMICAL USE IN THE HOME.¹

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INTRODUCTION.

The fats in the ordinary diet fall naturally into two groups, those eaten because they happen to be components of foods, like the fat in milk, meats, or fish, and those like butter, salad oils, or lard, which are added to other foods in cooking or serving. The housekeeper interested in the economical use of fats in the home must take into consideration fat as contributed by both groups. Obviously, the kind and quantity of the first group of fats eaten are determined by the foods making up the diet, and this is governed largely by individual tastes and local or family food habits. As regards this group, economy involves chiefly the proper selection and combination of foods containing fat in abundance with other foods containing little of it, so as to secure a diet supplying the proper proportions of protein and carbohydrate as well as fat. As this matter

¹ Prepared under the direction of C. F. Langworthy, Chief, Office of Home Economics.

NOTE.—This bulletin contains information regarding the character, selection, and use of edible fats in the home, much of the material being based on investigations made in the laboratory of the Office of Home Economics of the States Relations Service. It is of interest to teachers and students of domestic science, housekeepers, and others concerned with the problems of food selection and preparation.

of the nature and use of foods (some rich in fat) has been considered in other bulletins of this series, the present publication is concerned chiefly with the second group, or the added fats. For convenience the added fats may be subdivided into table and culinary fats. Table fats are those like butter and table oils, which are most commonly used as an accompaniment to food to secure a desired flavor or texture, and culinary or cooking fats are those which are incorporated with other foods (as shortening) or used as a medium for cooking foods, as in frying. Economy in the use of the added fats involves the intelligent selection of the different kinds, so as to secure the sort best adapted for a particular purpose, and the careful use in the home of the fats selected. It is the purpose of this publication to consider briefly the nature of fats, their value in the diet, and their digestibility; to describe the great variety of table and culinary fats on the market; and finally, to consider the economical selection and use of fats in the home. It is believed that such knowledge will prove helpful in buying and using fats to the best advantage.

GENERAL NATURE OF FATS.

The appearance and physical properties of the common fats and oils used for food purposes are too well known to require much description here. Chemically considered, fats consist chiefly of glycerids of fatty acids. The fatty acids whose glycerids are most common in edible fats are oleic, linolic, palmitic, and stearic. One fat differs from another primarily in the proportions of these esters which it contains and in the presence or absence of small quantities of other substances, such as free fatty acids and characteristic flavoring and coloring bodies.

The melting point or hardness of any fat depends on the relative proportions of these acids present, and fats containing large amounts of combined oleic and linolic acids are soft or liquid, while those containing large amounts of palmitic or stearic acid are solid. This follows whether the respective acids are combined as triglycerids or as mixed glycerids.

The color of some of the crude fats and oils varies from light yellow to red, or even black, but the refining processes remove a great proportion of the color-giving bodies, and the pure fats and oils are a pale yellow or colorless when liquid, and white or creamy white when solid.

The flavors and odors of fats are probably due to the presence in them of small amounts of difficultly removable substances rather than to specific properties of the pure fats themselves, in view of the fact that flavors and odors become much less noticeable the more completely the fats are purified. The characteristic flavor of butter, for example, is due to the absorption by the fat of the substances

formed in the fermentation of milk and cream by lactic acid and bacteria and to the presence of small particles of the curd. Similarly, the by-products, such as butyric acid, which are formed by the action of undesirable bacteria, may be absorbed by the fat and give rise to the undesirable flavor of butter of poor quality or that which has deteriorated. Musty flavors are doubtless due to the presence of the products of metabolism of molds which may be present in the fats. In the case of some fats, like those of beef and mutton, or the fish oils, it has apparently been impossible to remove entirely the flavor-giving substances by the ordinary methods of refining.

The exact nature of the compounds causing the rancid taste and odor of fats is not known. It is believed by some investigators that free and unsaturated fatty acids are first formed by the hydrolysis of the fats and that in the presence of light and air these fatty acids are oxidized to odoriferous compounds (aldehydes, ketones, etc.), the presence of which is thought to be identical with rancidity.

Very little is known of the nature of the combinations formed when culinary fats and other food materials are mingled in doughs, batters, etc. It is not definitely known to what extent these are mechanical mixtures and to what extent the ingredients have undergone chemical and physical changes. It is probable that the texture, and consequently the thoroughness of digestion of the finished bread or cake, depend in some degree upon such factors, and more information on this subject is desirable in order that the culinary processes may be more completely understood and controlled.

THE PLACE OF FATS IN THE DIET.

The chief value of fats in nutrition is that they furnish energy which the body requires to perform its work. The ideal diet should contain sufficient quantities of fat and carbohydrates to insure it the required amount of energy, as well as a sufficient quantity of protein to supply the necessary nitrogen for growth and repair of the body, also mineral matter for growth and other body needs, and vitamins or similar bodies required to render the diet adequate for maintenance. Since fats furnish $2\frac{1}{4}$ times as much energy, pound for pound, as do proteins and carbohydrates (1 pound of fat furnishing about 4,000 calories, and 1 pound of protein or carbohydrate only about 1,800 calories), and since they are both wholesome and palatable, they are very commonly used to increase the energy value of the diet. Furthermore, they are especially useful as a source of energy where an excess of carbohydrates in the diet is to be avoided, as in cases of diabetes or certain forms of indigestion.

The consumption of some fat is apparently universal, although the amount eaten varies within rather wide limits. The diet in the polar regions represents one extreme, fat being used in quantity with

meat, which is the chief article of diet. Though it seems to be less well known, it is nevertheless true, that fats are also eaten in considerable quantity in tropical countries, as is evident when one recalls the coconut oil of the South Sea Islands and the olive oil and other fats so much used in cookery in other regions characterized by a very warm climate. As everyone knows, dwellers in temperate regions use fat in the diet in many ways, which are determined largely by the prevailing food habits and the kinds of fat procurable, and in quantities which bear a more or less direct relation to the amount of physical work performed. Men engaged in severe work out-of-doors often eat large quantities of fatty foods. Workmen in lumber camps, for instance, relish a diet of pork and beans and other fat foods which would be too hearty for the office worker or clerk. It is difficult to obtain any definite figures for the quantity of fat eaten by the average person, but in 1,300 dietary studies of families, carried out among different races and in different countries, it was found that the average quantity of fat eaten was about $4\frac{1}{2}$ ounces per person per day, the variation recorded being from $1\frac{1}{2}$ to 13 ounces per person per day.

While fats and carbohydrates may replace each other to a considerable extent, recent investigations indicate that some carbohydrate supplied by the food or formed in the body from protein is essential for the combustion of fats in the body. Experts in nutrition and dietetics, therefore, believe that neither one should be used to the exclusion of the other.

DIGESTIBILITY OF FATS.

While all fats yield approximately equal amounts of energy when burned outside of the body, the energy which the body actually derives from each is dependent upon its digestibility; that is, the proportion which the body retains. The digestibility of a number of the individual fats¹ has been determined, and the information at present available indicates that fats in general are very thoroughly digested; more so, indeed, than the animal or vegetable proteins and the starch occurring in the ordinary mixed diet. Such slight differences as have been observed in the digestibility of individual fats evidently correspond to differences in their melting points. Available evidence indicates that fats such as mutton fat, having a melting point higher than the body temperature, are less completely assimilated than those melting at a lower temperature, such as lard, butter, olive oil, and cottonseed oil. Also, it has been shown by feeding experiments with laboratory animals that animal and vegetable stearins (melting above body temperature) are only

¹ U. S. Dept. Agr. Bul. 310 (1915).

very slightly assimilated by the body when eaten alone, whereas, if mixed with palmitin and olein digestibility is increased because, no doubt, the mixture has a lower melting point than the stearin by itself.

The digestive disturbances often attributed to eating fat are probably due not so much to the inability of the body to digest the fat itself as to other factors, chief among which are bad cooking, overeating of foods containing fats, and rancidity. Laboratory experiments have shown that under some conditions, when fats are overheated, a chemical compound called acrolein is formed. This substance is especially irritating to the mucous membranes of the eyes, nose, and throat, and it is well known to housekeepers that when fats are scorched vapors are given off which cause the eyes to water. If any of these vapors were occluded in the food during frying it seems probable that similar irritation would be produced on the delicate mucous membrane of the digestive tract. Obviously, such digestive disturbances can not be cited as proofs of an incomplete digestion of fats.

Disagreeable sensations are experienced by some people after eating large quantities of foods such as meats containing much fat interspersed with the muscular tissue, and overrich puddings or salads. This may be explained by the fact that the digestive juices of the stomach have little solvent action on such nonemulsified fats and are thus hindered from digesting the protein which is covered by or very intimately mixed with the fat. The passing of the food through the pylorus into the small intestine is thus delayed until the fat has become separated from the lean portions by the enzymic and mechanical action of the stomach. For this reason very fat meats, for instance, remain a longer time in the stomach than lean meats, although in the end they are as thoroughly digested. Similar digestive disturbances are sometimes experienced after eating fried foods (cooked without scorching) or foods in which fat is incorporated in such a manner that it prevents the digestive juices from acting upon the protein and carbohydrates. This delayed digestion is often mistaken for diminished or incomplete digestion. Fats which have become rancid, even though the rancidity is not sufficiently marked to influence the flavor very much, may cause digestive disturbances in some people. That this is not always the case is evidenced by the fact that there are some oriental people who eat rancid butter or oils apparently by preference.

It must be remembered that there are some persons whose systems can tolerate little if any food rich in fats. This, like the inability of some to eat strawberries, onions, or other foods, without digestive disturbances, is a matter of individual peculiarity.

SOURCES AND KINDS OF EDIBLE FATS.

The fats eaten in the ordinary mixed diet are furnished chiefly by such foods as fat meats, butter, milk, and cream, but are also present in smaller amounts in pastry, breads, eggs, cheese, cereals, etc. Fat meats like pork (including lard) and beef furnish about 59 per cent of the total fat in the average American diet, ac-

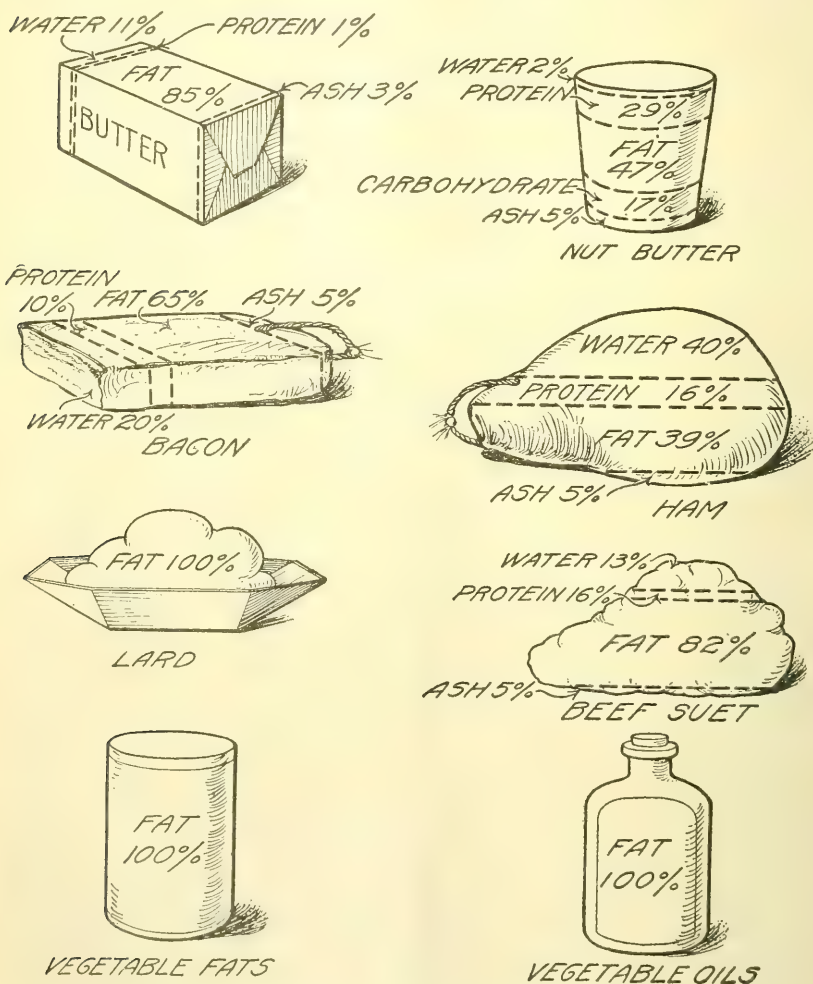


FIG. 1.—Composition of some common fatty foods.

ording to the results of about 400 studies as reported in an earlier publication of this office.¹ The same investigations showed that dairy products, including butter, milk, cream, and cheese, furnish about 26 per cent of the total fat; cereal products, including

¹ U. S. Dept. Agr., Office Expt. Stas. Circ. 110 (1911).

cakes and breads, about 9 per cent; eggs about 3 per cent; and fish about 1 per cent. Some kinds of fish contain considerable fat and offer a means of adding it to the diet. One-tenth of the edible portion of such fish as the catfish, salmon, butterfish, trout, shad, and a smaller proportion of other common fish consists of fat. The composition of some of the foods which are important sources of fat in the diet is shown in figure 1. The amount of energy supplied by these foods depends on the quantity of fat which they contain, the pure fats like lard or vegetable fats furnishing 4,080 calories per

STANDARD FOR COMPARISON



1000 CALORIES



BUTTER, 3,490 C.



NUT BUTTER, 2,740 C.



BACON, 2,835 C.



HAM, 1,885 C.



LARD, 4,080 C.



BEEF SUET, 3,425 C.



VEGETABLE FATS, 4,080 C.



VEGETABLE OILS, 4,080 C.

FIG. 2.—Energy furnished by one pound of common fatty foods.

pound, and those containing other ingredients like water or protein naturally having a lower energy value. For comparison the energy furnished by 1 pound of some of the common fatty foods is shown graphically in figure 2.

Not many years ago the fats used in this country were obtained almost entirely from the two groups of farm animals, cattle and hogs. Butter and cream were the ordinary table fats, and it was the general custom for each family to obtain its own supply of lard, which was the chief cooking fat, from the pigs slaughtered

on the farm. Beef and mutton fats, or tallows, as they were generally known, were used in cooking to some extent in the form of "dripping" obtained from cooking meats, but found a much wider use for candle and soap making. Chicken fat was also used in a limited way. As the population began to concentrate in cities and towns, the introduction of central slaughterhouses and rendering plants made it possible to obtain both meat and fat separately in such ways as met individual requirements, and home rendering of fats quite generally disappeared except in rural regions. The increasing population created a demand which soon exceeded the available supply obtained from slaughtered animals, and this made it necessary to seek additional sources of edible fats. Naturally, olive oil, used for food purposes in some parts of Europe and the Orient and less generally in the United States, suggested the possibility of the utilization of other vegetable fats, and as the methods of refining were improved cottonseed oil came to be very commonly used, and, to a less extent, coconut, peanut, and corn oils. At the present time there are also a number of vegetable fats on the market, some of which are simply refined and used alone or in admixture, while others have been treated by special processes designed to render them harder or otherwise changed in character. In the following pages general information is given regarding the nature, source, and use of some of the more important edible fats.

ANIMAL FATS.

BUTTER.

Butter is the most popular and widely used of all fats in the United States, it being estimated that from 17 to 18 pounds per capita are consumed yearly, most of it for table purposes. Its food value is due largely to the energy it furnishes, which is about 3,500 calories per pound. It consists of the fat of milk, some water, and a little curd and added salt. Butter is of two kinds, salted and unsalted. Commercial butter contains approximately 82.5 per cent of fat, which consists chiefly of palmitin and olein with small amounts of myristin, butyrin, and other glycerids of the fatty acids. The color varies considerably with the nature of the food materials eaten by the cow; the yellow is deeper in summer when green food is eaten. It is a common practice to add vegetable coloring matter, especially during the winter months, to intensify the natural color. Since butter tends to deteriorate easily, care in its manufacture is necessary to secure a wholesome product with good keeping qualities. The milk from which the cream is separated should be free from disease-causing bacteria as well as from microorganisms which would produce undesirable flavors or odors in the butter. For this reason

in many creameries the milk or cream is pasteurized to kill undesirable organisms, and the ripening of the cream is started and controlled by the addition of a pure culture of bacteria which produce the desired flavors. Care must also be taken in the handling and storage of butter to prevent it from becoming contaminated with disease-causing bacteria or from absorbing undesirable odors or flavors. Such precautions, necessary to secure a wholesome product, naturally add to the cost of butter, but obviously from the standpoint of health are well worth the higher price. Butter of inferior quality is frequently treated by a commercial process which removes the objectionable odor and taste and then marketed as renovated or "process" butter. As many housekeepers know, strong butter can be made more palatable by washing it repeatedly in clean, cold water and then resalting; if the final washing is done in milk a better flavor is obtained. The commercial process of renovating butter is somewhat similar to this domestic process. The butter is melted, and air is blown through it until the undesirable flavor due to volatile substances is carried away. The product is then emulsified with soured milk and worked like ordinary butter. Renovated butter sells for a lower price than fresh butter, and for this reason it is used quite extensively in cookery, and to some extent for table purposes. If the process is carefully carried out it is of good flavor. Naturally, the sale of renovated butter as fresh butter is prohibited by the Federal and State pure-food laws.

Rendered butter, called "ghee" in India, is preferred by some people to ordinary butter. It is easily prepared by melting the butter with or without adding water and allowing the mixture to become cold, when the layer of butter fat is removed; if desired, salt is added to replace that removed in rendering.

CREAM.

Cream, which contains from 18 to 40 per cent of fat, should be regarded as one of the available fats. It is generally used as a table fat, being served with cereals and fruits, as a constituent of ice cream, and plain or whipped with jellies or puddings. In rural regions, where the supply is large, both sweet and sour cream are commonly used for shortening, but to a less extent in cities and towns, where cream is more expensive. Cream is very palatable to most persons, and for this reason it is often prescribed by physicians for people who require a diet rich in fats. A form of cream more common in England than here, and known as "Devonshire Clotted Cream," is prepared by heating to about 180° F. whole milk on which the cream has been allowed to rise, cooling the mass, and skimming off the cream. It has a light-yellow color and a character-

istic nutty flavor, is much thicker than ordinary cream, and contains about 60 per cent of fat.

LARD.

Pork fat is one of the more widely used of the animal fats, being eaten in a variety of forms, such as bacon, ham, fresh and cured pork, and lard, which is used principally for culinary purposes. The best grade of lard, commonly known as leaf lard, is rendered from the fat which surrounds the kidneys of the animal, but commercial lard is often rendered from any or all of the fatty portions of the animal and could be more exactly termed pork fat. Since lard contains a relatively small amount of the harder constituents of fats, it has a moderately low melting point and so is easily handled in the preparation of doughs. This is a reason why some housekeepers prefer it to harder fats for shortening purposes, especially in cold weather. For some special shortening purposes lard may be too soft and require hardening by chilling before use. Pure lard should be white in color and practically free from taste or smell. Home-rendered lard may contain varying amounts of water, according to the mode of rendering, but that containing the smallest quantity has the best keeping qualities; the commercial product contains practically no water. Formerly lard was sometimes adulterated by the addition of different substances, but with more stringent regulations this has practically ceased, and the commercial product is generally wholesome and prepared under sanitary conditions from animals which have been inspected before slaughter.

BEEF FAT.

Beef fat contains a large amount of stearin and is therefore harder than either butter or lard. The hardness and other characteristics of beef fat, as well as other animal fats, vary somewhat according to the part of the body from which they are obtained; for example, brisket fat, from the breast of the animal, is softer than rendered suet, the fat surrounding the kidney. The hardness of beef fat, and its rather pronounced flavor, which is unpleasant to some people, have doubtless prevented its more extensive use for culinary purposes. Many attempts have been made to remove the flavor, but apparently no method has been discovered which gives results satisfactory enough to warrant its use on a commercial scale. Finely chopped unrendered suet is quite often used for shortening in such dishes as suet puddings. Rendered beef fat, or tallow, as it is sometimes called, is used by many people for shortening purposes, being mixed with butter or some other fat to soften it. It is sometimes sold in the market for this purpose, and in many homes beef suet or small scraps of fat trimmed from roasts, etc., are rendered for use in shortening and

frying. Rendered beef suet has no general use in this country as a table fat, but in Europe people with small incomes often eat so-called drippings on their bread in place of butter. These drippings are sometimes obtained from roasting or broiling beef, but in many cases are simply rendered suet.

MUTTON FAT.

Mutton fat, called also mutton tallow or suet, contains a relatively large amount of stearin and is, therefore, classed commercially as a hard fat. It is used in the manufacture of stearin for soap making, and small quantities of the more highly refined grades are used in the manufacture of toilet creams and other cosmetics. Edible mutton fat is now prepared in considerable quantities, the mutton tallow and mutton stearin being used as ingredients of lard substitutes and the mutton oil as an ingredient of the lower grades of oleomargarine. Mutton fat is eaten to some extent in most homes as a constituent of fat mutton or lamb and in gravies served with such meats. Mixed with softer fats it is occasionally used in the home for shortening and frying, but much less so than pork and beef fats. This, no doubt, has been due to the characteristic mutton flavor, which is unpleasant to many people, to the hardness of the fat, and in some degree to the smaller available supply.

POULTRY FATS.

Poultry fats resemble butter and lard in consistency, and recent investigations show them to be as thoroughly digested as other fats of the same degree of hardness. That they are wholesome and palatable is indicated by the fact that they are very frequently eaten as a constituent of gravies, broths, and soups. Many housekeepers consider poultry fat very useful and desirable in cookery, but the total quantity of poultry fats used in this manner is relatively small, owing to the limited supply. In the household small quantities are obtained in dressing and cooking fat poultry, but the only available commercial supply is that obtained from very fat birds drawn at the market for those who do not desire the excess fat. Chicken fat is the poultry fat most used for cooking purposes in the United States, as is natural, since chickens are the commonest table poultry. Goose fat, so well known in Europe, is used in this country chiefly by families of foreign birth or descent who keep to old food customs.

OLEOMARGARINE.

A discussion of animal fats would not be complete without some mention of oleomargarine, called "margarin" in Europe. The term margarin was at first used to designate a mixture of fats, composed of such proportions of palmitin and stearin that it closely resembled

margaric acid, for which it was often mistaken, and so it was given the name "margarin." Later, when soft beef fat, or oleo oil, became an important component of this mixture, it was called oleomargarine or oleo. The name does not at present, however, indicate the composition of the oleomargarine. The principal fats used in its manufacture in the United States are oleo oil, neutral lard (that is, a specially rendered lard), and cottonseed and other oils. All these ingredients must be pure and prepared with care in order that none of them shall have any marked taste or odor. These are mixed in such proportions as will give the final product a melting point very near that of butter. After being thoroughly mixed the fats are churned with a small quantity of milk and sometimes cream, the proportions of these used depending upon the quality of the product desired. In the preparation of high-grade oleomargarine varying quantities of butter are also added. The resulting product is then washed, salted, and worked as in ordinary butter-making processes. Owing to the ease with which a highly colored oleomargarine might be sold as butter, it is illegal to sell oleomargarine unless it is plainly labeled as such, and the practice of coloring it to imitate butter is discouraged by a heavy tax. Oleomargarine is not used as extensively in this country as in Europe, where it serves both for table and culinary purposes. If prepared from pure materials and under sanitary conditions, it is a wholesome fat, which, according to European investigators, is well assimilated. It has an energy value of about 3,500 calories per pound.

VEGETABLE FATS.

Vegetable fats are prepared on a commercial scale from oil-bearing seeds and fruits and must ordinarily be freed from disagreeable flavors and odors as well as from dirt, by-products, and harmful constituents. In general, the process involves cleaning the seeds or fruits and subjecting them to hydraulic pressure. Cold-pressed oils usually receive no further treatment. When the seeds or oily pulp are hot pressed, however, the raw oil is likely to contain free fatty acids and other organic compounds of a disagreeable nature which make refining necessary. The refining process is adapted to the properties of the oil in question.

OLIVE OIL.

Olive oil is obtained by subjecting the ripe olives to pressure. The best grade, known as virgin oil, is obtained from perfect olives of the proper degree of ripeness. Lower grades may be obtained either by crushing and pressing an inferior quality of olives or by a second pressing of the residue from the first pressing of the better grades of fruit. The only refining or purification of the better

grades of oil necessary is filtration to remove foreign matter. In the United States olive oil is used almost exclusively for table purposes, being a very common salad oil. In localities where it is produced, especially in southern Europe, it is used for cooking as well as for table purposes, owing to the larger and more readily available supply (especially of the cheaper grades) and to the relatively limited supply of animal fat in such regions.

COTTONSEED OIL.

Cottonseed oil in its crude form is obtained as a ruby or dark-red oil by subjecting the seeds of the cotton plant to great pressure. This crude oil was at first used for soap making and other industrial purposes, but with the increased demand for culinary fats improved methods of refining the crude oil, such as treating it with caustic alkali, fuller's earth, distillation with steam, etc., were developed. These serve to modify greatly the color, odor, and taste, and the best grade of table oil has a light-yellow color and a bland flavor. The refined oil was first utilized in the preparation of various lard substitutes by mixing with it hard animal fats to produce a substance having a consistency similar to lard. Other methods have been developed, and a wide variety of cooking fats prepared from cottonseed oil are now on the market. More recently salad oils have been prepared which are wholesome and palatable and are being used in increasing quantities for table purposes.

PEANUT OIL.

Peanut oil is not used to any extent for culinary purposes in this country, but some is imported for use as a salad oil. In Europe, where it is obtainable in relatively large quantities, it is used quite extensively both as a table oil and for cooking. When prepared by the cold-press method the characteristic peanut flavor is not noticeable and the product is bland and palatable. In the past the peanut oil produced in this country has been used in the crude state for industrial purposes, but an attempt is being made to develop the peanut-oil industry in this country and to encourage the more extensive use of the refined oil, which is now more expensive than cottonseed oil, but less expensive than olive oil of similar grade.

COCONUT OIL.

Coconut oil is prepared by pressing the dried meat of the coconut, which is known in the trade as copra. The crude oil is used for cooking purposes in tropical countries where the oil is prepared. In this condition the fat melts at about 70° F. and is a liquid in summer or in warm rooms during the winter. Refined coconut fat has little marked taste or odor if fresh and carefully prepared, and when solid

is white in color. It has only recently come into use for culinary purposes but bids fair to become an important cooking fat. There are a number of coconut-oil products on the market, but these are not much used for home cooking. They are extensively used in bakeries and similar establishments, one reason being that they can be obtained with a considerable range of hardness, so that they are useful for many special purposes. For instance, one of the coconut fats is combined with sugar for use as a filling for some sweet crackers.

CORN OIL.

Corn oil is prepared from the germ of the corn which is obtained as a by-product in the manufacture of cornstarch and glucose. The germs are ground and subjected to pressure which removes the oil. Some studies have been made of the use of corn oil for shortening purposes. Pastry made with mixtures of lard and corn oil in amounts not exceeding 10 per cent of the latter gave results identical with those in which lard alone was used.¹ When properly refined, corn oil is a wholesome product and is marketed to some extent as a table oil. Large quantities of the crude oil are used for industrial purposes.

MISCELLANEOUS OILS.

In addition to the above-mentioned vegetable oils there are a number of others, such as soy bean, sunflower, sesame, and colza or rape-seed oils, which may be mentioned here. When carefully prepared these oils are of a yellow color and bland flavor and are used for food purposes in those countries where the particular seeds are obtainable in large quantities and the supply of other edible oils is limited. Walnut and similar nut oils, produced in some countries where the nut crops are large, are of good flavor and find a use for salad purposes.

There is some attempt being made to promote the utilization for table purposes of oils expressed from the kernels of the stones of such fruits as the apricot, peach, and cherry. Inasmuch as these stones are available in quantity as a waste product of the drying and canning of fruits, and the expression and refining of the oil may be done at small cost, they offer an additional source of edible oil.

HARDENED VEGETABLE FATS.

Hardened vegetable oils, technically known as hydrogenated oils, which have much the same consistency as lard or butter, have been put on the market within recent years. They are commercial pos-

¹Ann. Rpt. Ohio Dairy and Food Comr., 21 (1906), pp. 18-23.

sibilities owing to the fact that as a result of a long series of laboratory experiments processes have been discovered by which oils may be transformed into a product of any desired hardness by chemically adding hydrogen to them. This reaction takes place, for instance, when finely divided nickel, hydrogen, and the oil to be hardened are intimately mixed under proper conditions. The nickel does not enter into the composition of the hardened fat, but is removed and used repeatedly in the preparation of other batches. The hardened oils are generally white in color, have no appreciable odor or taste, and are less likely to become rancid than the original oil. A number of these fats, marketed under a variety of trade names, have proved popular and appear to be of quite wide application. This hardening process may also be of special value in the future utilization of some oils like the fish oils, which, because of objectionable flavors and odors, are not entirely suited for edible purposes in their natural state.

NUT BUTTERS.

Closely related to the nut oils mentioned above (see p. 13) are the nut butters prepared by grinding finely the meats of peanuts, almonds, or other nuts rich in fat, so as to produce an oily mass much like butter in consistency. Peanut butter is by far the most common of the nut butters. It is used chiefly as a filling for sandwiches, crackers, etc., though it finds some use in cooking. The nut butters can be made at home by grinding the whole nuts; a special nut-butter knife being furnished with some of the meat or food choppers. In addition to containing a large amount of fat, nut butters also contain considerable protein.

AVOCADO.

Although its oil is not extracted for food purposes, the avocado, commonly called the alligator pear, a tropical fruit which is becoming better known in some of our markets, contains as high as 20 per cent of fat in the edible portion. When used in the diet this must be taken into consideration as a source of fat.

THE SELECTION OF EDIBLE FATS.

In the selection of edible fats the principal considerations should be the purpose for which the fat is to be used, quality, price, and individual preference, since the energy which the body derives from different fats is about the same, and all are regarded as wholesome when of good quality. Custom, which influences to a considerable extent the choice of all foods, can, therefore, be subordinated to the more essential consideration of economy.

When purchasing fats for table use it should be remembered that they influence the wholesomeness of the foods with which they are served as well as the energy value and cost. The price of table fats depends largely upon their flavor and to a less extent on color, and in selecting them each housekeeper must decide how much she can afford to pay for these properties, since all the edible fats have practically the same energy value. In general it pays always to buy fats of such good quality that none will have to be thrown away through spoilage. In some instances a higher-priced article may be more economical in the end as, for example, clean, sanitary butter, as compared to a cheaper but less sanitary product. In some instances, where taste or flavor only is involved, a less expensive table fat may answer quite satisfactorily the purpose of a more expensive one. For example, the chief use of table oils is as an ingredient of salad dressings, and when a characteristic flavor is not especially desired, good grades of cottonseed and peanut oils, having a bland flavor, may be used, when these are less expensive than the corresponding grades of olive oil.

Fats used for shortening influence the appearance, flavor, texture, composition, keeping quality, and cost of the foods in which they are incorporated. In selecting shortening fats flavor and odor are to be considered, but attractive appearance and color are of less importance, since in cooking these are usually masked. Other qualities being equal, those culinary fats are more economical and desirable which possess the best keeping quality; that is, the least tendency to become rancid. Also, for general use shortening fats give the best results if they are neither too hard nor too soft to be easily mixed with the other ingredients of the dough at ordinary temperatures.

Fats used as a medium for cooking should be carefully selected, since they influence the flavor, appearance, and texture of the foods cooked in them, as is evident when one recalls the bad flavor imparted to fried foods by burned or rancid fat. Preference should be given to a fat which does not scorch too readily at the temperature most commonly used for frying. Experiments in the laboratory of the Office of Home Economics indicate that butter and lard scorch at a lower temperature than beef or mutton fats and cottonseed, peanut, or coconut oils. For this reason, therefore, the latter fats are preferable for deep frying, which requires high temperature.

Prejudice often exerts an influence on the selection of fats as well as other food materials, and these prejudices are often curious. For example, some persons who think that lard is not only indigestible, but also unwholesome, nevertheless enjoy bacon, which, of course, supplies pork fat in a different form. Such prejudices have little

or no basis of fact and should not exert too much influence on the selection of any food material.

ECONOMY IN THE USE OF FATS.

In minor details the practice of economy in the use of fats must vary according to conditions in different homes, and each housekeeper must determine for herself the manner in which economy may be secured in her own household. There are some general suggestions, however, which are worth consideration.

Economy in the use of table fats probably may best be secured by avoiding careless or needless uses. The quantities of butter, salad dressing, or table oils generally eaten by the different members of the family should be observed, and the size of the portions served governed accordingly, so that the left-overs will be small. One should serve all of these that a person will use, but no more. In some homes this possible economy is not considered sufficiently important to warrant the effort. In hotels and restaurants, however, where profit is increased by the prevention of unnecessary waste, this matter is given considerable attention, and careful observations have been made to determine the average quantity of butter eaten per person. It has been found that if too small a portion is served more second orders are called for, and much butter is thus wasted, because the total will so often exceed the person's desire for it. On the other hand, if the portions served are too large, a considerable quantity will be unused. As a result of such observations many hotels and restaurants have regulated the size of portions so as to give satisfaction and yet insure the smallest amount of waste. A common size is a block $1\frac{1}{4}$ inches by $1\frac{1}{4}$ inches by $\frac{1}{2}$ inch (weighing about one-half ounce), which is readily obtained by cutting a pound print of butter into 32 pieces with a cutter designed for the purpose, or with a sharp knife slightly warmed. Many housekeepers prefer to make the butter into "butterballs," using for the purpose the wooden paddles which may be bought from house-furnishing stores. The size of the balls can be regulated according to the needs of the individual.

Where table fats (chiefly butter and cream) are used in cookery to give flavor, economy demands that they be so used as to secure the maximum of quality in texture or flavor from a minimum quantity of fat. It is a waste to use more than a good recipe calls for. It is well known that too much butter makes a cake soggy, while a salad dressing with too much oil tastes "fat." It is more economical to stir butter into cooked vegetables just before they are served rather than while cooking, and the flavor thus imparted is more pronounced. Furthermore, if added before cooking

much of the butter is lost unless the water in which the vegetables are boiled is served with them. Instead of adding butter to vegetables many people cook fat ham, bacon, or salt pork with them and relish the characteristic flavor thus imparted. As another example of the economical use of butter in cookery may be cited the frying (*sautéing*) of eggs, rice cakes, etc., in a mixture of butter, to contribute flavor, and some such fat as lard or drippings to give a sufficient quantity of fat for the cooking process. Also, part butter (or cream) and part lard is frequently used in shortening pie crust, biscuits, etc. A mixture of equal parts of carefully rendered beef suet, lard, and butter, known as "butterschmaltz," is used in some regions of the country for shortening purposes in place of table butter.

Since shortening fats are used to secure texture more often than for their distinctive flavor, it is possible to utilize a greater variety of fats for this purpose than for table use. Oftentimes a home-rendered fat may be economically substituted for butter, lard, or vegetable fats for shortening purposes. For instance, beef-brisket fat is softer than suet and, if well rendered, can be used to make gingerbread, spice cake, and similar dishes in which the spice or molasses used masks the flavor of the fat. A possible economy, more common some years ago than now, is the use of chopped, unrendered suet for shortening in such foods as suet puddings, or the use of finely chopped salt pork for a similar purpose in some spice cakes. Occasionally cheese can be used both as a shortening and to give flavor, as in making Brown Betty, cheese biscuits, etc., as is mentioned in another bulletin of the Department.¹

The use of too much fat for shortening is not only extravagant but may be unhealthy, because the frequent ingestion of large quantities of very fat foods often produces digestive disturbances. All that a dish requires to be of standard quality should be used, but no more. It is just as possible for food to be overfat or overshoot as it is to be oversweet, and in the preparation of cakes, batters, etc., recipes which call for an unusually large quantity of fat should be avoided for the sake of health as well as economy. Another possible economy is the selection of a food which requires little or no fat in its preparation in place of a similar kind of food rich in it, when some other ingredient of the meal supplies a generous amount of fat. For instance, sponge cake instead of pound cake, or beaten biscuit instead of butter cakes, might well be selected when very fat meats or other fat dishes form a part of the meal.

In frying, fat serves principally as a medium for transmitting the heat needed for cooking. The flavor is modified also, as is evident

¹ U. S. Dept. Agr., Farmers' Bul. 487.

from the fact that foods like croquettes when fried in fat have a different taste from those baked in the oven. Since all foods in frying absorb some fat, their nutritive (energy) value is increased. Up to a certain point this may be an advantage, but it is desirable to regulate the amount absorbed in order that the foods may be of good flavor and texture and not overfat. An excess of fat soaked up by the food is not only waste, but lowers the quality and may give rise to digestive disturbances in the case of some persons.

The temperature of the fat during deep frying has considerable influence upon the quantity of fat which the food absorbs, and some preliminary studies have been made in the laboratory of the Office of Home Economics to determine satisfactory temperatures. A doughnut batter was prepared from flour, egg, milk, sugar, and baking powder, and portions of uniform size and shape were fried for definite periods of time in beef fat, lard, cottonseed oil, coconut fat, and peanut oil at a number of different temperatures. It was found that there was a definite temperature for each fat at which the batter soaked the smallest quantity of fat and was most satisfactorily cooked as regards texture. This temperature was about 360° F. for beef fat, 350° F. for lard, and 390° F. for cottonseed, coconut, and peanut oils. Subsequent chemical analyses of the doughnuts showed that if this temperature were lowered 20° F. for the animal fats and 40° F. for the vegetable fats the quantity of fat absorbed by the doughnuts was increased approximately 25 per cent. Although these temperatures may vary somewhat with different lots of fat, owing to slight variations in composition, it may be stated in the light of these experiments that for successful deep frying vegetable fats should be heated from 30° to 40° F. higher than animal fats. Mixtures of beef or mutton fats with some of the oils and softer fats were also tested. With mixtures of equal amounts of hard and soft fats the optimum temperature was midway between that of the two separate fats. There is less danger of a fat being too hot than being too cold for frying foods, since a tendency for the food to burn is more easily noted by the cook than a tendency for it to soak fat. Also, if the fat is too cool more of it is absorbed by the foods. However, fats used for deep frying should never be heated high enough to scorch, as the burned flavor and odor are very hard to remove, and foods fried in scorched fats are of poor quality. A thermometer which will register as high as 420° F. is very useful for measuring temperatures in deep frying, but it is rather expensive, and a fairly close idea of the temperature may be obtained by noting the time taken to brown a 1-inch cube of bread completely immersed in the hot fat. Experiments in the laboratory of the Office of Home Economics indicate that vegetable fats are at the most satisfactory

temperature for deep frying when the bread is cooked to a golden-brown color in one-half minute or is well browned in one minute. Lard, beef, and, probably, mutton fats are hot enough when the bread is cooked to a golden-brown color in one minute or is well browned in one and one-half minutes.

In sautéing, or pan frying, the food is cooked on a layer of fat rather than completely immersed in it, as in deep frying, and for this reason there is less opportunity for the food to soak fat. There is more danger, however, that the food so cooked will be burned unless care is taken, since the pan may become too hot and the relatively small amount of fat may soon be used up and the food stick to the pan. For this reason a fat which does not scorch at a low temperature is especially desirable for sautéing; butter, for example, being less satisfactory in this respect than lard or beef fat. If the butter flavor is desired in pan-fried foods, a little butter can be used with a harder fat or the butter can be added after cooking. Otherwise great care must be exercised to avoid scorching.

UTILIZATION OF WASTE FATS.

In many homes the failure to utilize left-over or discarded portions constitutes the chief waste of fat. Many housekeepers who are economical in other ways do not give sufficient attention to this matter, and, as a result, there is apt to be more fat wasted than either protein or carbohydrate. In cities this is evidenced by the fact that there are large and profitably conducted concerns whose only business is the recovery and sale of grease from garbage. As this grease is always sold for soap making or other industrial purposes, it is not a complete loss, though lost to the housekeeper, and much of it, if properly saved in the home instead of thrown in the garbage, might have been used for culinary purposes. In country households there is often better opportunity for utilizing waste fats than in the city, and it is quite possible that some of the fat ordinarily fed to the pigs and chickens might be more economically utilized if the edible portions were carefully rendered and used for cooking purposes and the remainder used for soap making. The latter is not such a difficult process as many persons suppose. The necessary lye may be readily purchased at a low price, and simple directions for soap making usually come with it.

From the standpoint of economy it is desirable for the purchaser of meat to secure all the fat which he pays for in a particular cut. The dealer pays a flat rate per pound for the carcass, which includes the lean meat, fat, and bone. The fat must either be sold with the meat or else removed and the lean meat sold at a higher price to insure a profit. Many butchers in preparing beef, mutton, or poul-

try for delivery remove much of the fat in order to make the meat appear more attractive. The purchaser often does not take the trouble to ask for this fat, even though he may have paid for it at the same rate as the meat. If this fat were secured, as is frequently the case with the excess bone and trimmings which are used for soup making, it could often be rendered at home and used to supplement cooking fats. Sometimes very large and fat cuts of meat are sold at a relatively low price per pound. While the purchaser may think that thus a bargain is being secured, it is usually true after allowance has been made for a large quantity of fat and bone that the price paid for the lean portion is considerably higher than appears at first thought. In such cases it is especially desirable that the excess fat be utilized in the home.

If one so desires, bits of fat meat, portions of butter, etc., left over from the table may be saved, rendered (if necessary), clarified, and used for cooking. While there may seem to be some esthetic objection to this procedure, this is not necessarily a serious one under family conditions where good health prevails, since if properly rendered the fat is sterilized. The better way, however, is to effect the same saving by taking care in serving that each portion is approximately what will be eaten. Under commercial conditions the use of table left-overs is entirely unjustified, since the person served can know neither the circumstances under which they were obtained nor the quality of the material which he may eat. The pieces of excess fat trimmed before cooking from roasts, steaks, or chops should be saved as well as the drippings tried out in cooking. Drippings from fresh pork may be clarified and used like lard. Beef fat or drippings and small quantities of lamb fat, if fresh and carefully clarified, may be added to lard or other soft fats for deep frying. Sausage, ham, and bacon fats may be used as they are for frying and warming up foods, since the characteristic flavors which they impart are relished by many.

In some parts of the country fat is used (but less now than formerly) to preserve meats for a limited time. The thoroughly cooked meats are placed in clean earthen jars or wooden tubs, and over them is poured a sufficient quantity of hot melted lard or beef suet to cover. The hot fat sterilizes the surface of the meat and on cooling forms a protective coating against the action of the air, bacteria, or mold spores. So far as is known this method has not been tested experimentally, but meat so treated is said to keep very well, providing it is thoroughly cooked and the fat has been heated sufficiently to sterilize it and drive off the water. To prevent the fat from becoming rancid it is desirable to store the jars in a cool, dark place. Carefully rendered beef suet or mutton tallow may also be

used in the place of paraffin, which it closely resembles in consistency, to seal the tops of jelly glasses. To cite another instance, a spoonful of salad oil may be poured on top of the liquid in an opened bottle of pickles or olives. This excludes air and so helps to keep the material in good condition until used.

RENDERING AND CLARIFYING FATS.

Beef or mutton suet and scraps of fat contain more or less muscle or connective tissue, which must be removed by rendering before the fat is available for most culinary uses. The household method of rendering generally consists in cutting the material into small pieces and heating it in an open kettle until the fat has separated out quite completely from the particles of tissue, which usually have become shriveled and browned. This tissue (called "scraps" or "cracklings") is then removed by straining, being pressed to remove the fat more completely. The scraps or cracklings are utilized in various ways in different parts of the country, being sometimes eaten as such and sometimes used as shortening. Some housekeepers prefer to render their fat with the addition of water, since they believe there is less danger of burning. However, this necessitates heating the strained fat until the water is driven off to secure a fat of good keeping quality.

The following method of rendering fats, found to be very satisfactory in the laboratory of the Office of Home Economics, may be applied in the home. The fat is cut finely with an ordinary household meat chopper or sausage grinder and is then heated in a double boiler until completely melted. The melted fat is then strained through a rather thick cloth (medium fine huckaback, for instance) to remove the finely divided bits of tissue. The advantage of this method is that since the material to be rendered is finely divided the fat separates readily from the inclosing tissue at a temperature very little above its melting point, and there is no danger of scorching it as in the older open-kettle method. This is of importance, since recent information shows that fats overheated in rendering do not keep as well as those which have not been heated too high. Also, there is no odor of scorched fat in the room during rendering. After the fat is rendered it should be carefully heated to make sure that it is free from moisture, and sterilized. This method of rendering fat is entirely satisfactory when the quantity of fat to be rendered is fairly small. The difficulty of using it on a large scale would depend chiefly upon the labor and cost of grinding the fat, for if a double boiler of sufficient size were not available one could be improvised by setting the kettle containing the fat in a larger kettle containing water. Pieces of wood or other material should be placed

on the bottom of the outer kettle to insure a layer of water between the two kettles and prevent the fat from becoming too hot.

Fats which have been saved when meats are cooked, or which have been salvaged in some other way, must usually be clarified—that is, freed from objectionable odors, tastes, or colors—before being entirely satisfactory for culinary purposes. A common custom is to cook a slice of potato in the fat, and this may help if the fat is fairly satisfactory to start with. A fairly successful household method for clarifying fats is as follows: Melt the fat with at least an equal volume of water and heat for a short time at a moderate temperature, with occasional stirring. Let the mixture cool, remove the layer of fat, and scrape off any bits of meat and other material which may adhere to the under side. Rendering or clarifying fat with milk gives quite satisfactory results in modifying odors and flavors. The procedure is as follows: To 2 pounds of fat (finely chopped if unrendered) add one-half pint of milk (preferably sour). Heat the mixture in a double boiler until rendered or thoroughly melted, stir well, and strain through fairly thick cloth. When cold the fat forms a hard, clean layer, and any dark material adhering to the under side of the fat may be scraped off. Sour milk, being coagulated, is preferable to sweet milk, since the curd remains on the cloth through which the rendered mixture is strained and is thus more easily separated from the rendered fat, which has acquired some of the milk flavor and butter fat.

Undesirable odors and flavors can be decreased in intensity or removed, if not too pronounced, by heating the fats with a good grade of charcoal, and the method is applicable to fats which could not be satisfactorily treated by the method first spoken of. To each pound of chopped, unrendered fat add 12 pieces of clean, hard-wood charcoal about the size of a walnut and render the fat in a double boiler, as described above. Allow the charcoal to remain in the melted fat for about two hours and stir the mixture occasionally. It is necessary to strain the fat through flannel or other closely woven cloth to remove all the fine particles of charcoal. Rancid odors, if not too pronounced, may be satisfactorily removed by this method. If the odor is very pronounced more charcoal is needed, and the mixture requires longer heating. It is interesting to note that the characteristic yellow color of the beef fat may be removed and a white, odorless fat secured.

SAVORY FATS.

Savory fats—that is, fats to which have been added some strong seasoning material, such as sage, marjoram, summer savory, or thyme—offer a satisfactory method of utilizing fats having pro-

nounced odors or flavors like those of beef or mutton. The specific flavoring bodies present in these seasoning materials are dissolved in the fats and mask the strong original flavors. Savory fats are useful for frying, warming up vegetables, etc., since they impart a distinct flavor to foods.

There are a number of recipes for the preparation of savory fats. The following have been tested and found to be satisfactory with mutton or beef fats:

SAVORY FAT, I.

To 1 pound of unrendered fat (chopped fine) add 1 slice of onion about $\frac{1}{2}$ inch thick and 2 inches in diameter, 1 teaspoon broken bay leaves, 1 teaspoon salt, and about $\frac{1}{8}$ teaspoon pepper. Render in a double boiler and strain.

SAVORY FAT, II.

To 1 pound unrendered fat (chopped fine) add 2 teaspoons thyme, 1 slice onion about $\frac{1}{2}$ inch thick and 2 inches in diameter, 1 teaspoon salt, and about $\frac{1}{8}$ teaspoon pepper. Render in a double boiler and strain.

SAVORY FAT, III.

To 1 pound unrendered fat (chopped fine) add 1 teaspoon thyme, 1 teaspoon marjoram, $\frac{1}{2}$ teaspoon rubbed sage, 1 teaspoon salt, and about $\frac{1}{8}$ teaspoon pepper. Render in double boiler and strain through fine cloth.

If it is desired to prepare a savory fat from a rendered fat the above recipes may be modified by melting the fat, adding the seasoning in the same proportion as above, heating the mixture gently for an hour or more, and straining. The following recipe has also been recommended for preparing a savory fat from a rendered fat:¹

To 1 pound rendered fat (melted) add 1 sour apple, 1 onion, and 1 teaspoon ground thyme or other sweet herbs tied in a small cloth. Cook together in oven or on the back of the stove until the onion and apple are well browned. Strain the fat through a fine cloth.

The kind and amount of seasoning recommended may be easily modified to suit one's taste. Potato chips and French fried potatoes cooked in each of the above fats were found to have no noticeable mutton or beef flavor. In order to remove all particles of the herbs added it is necessary to strain the savory fats through flannel or other closely woven cloth.

SOFTENING HARD FATS TO MAKE THEM MORE SATISFACTORY FOR SHORTENING PURPOSES.

Fats, like beef or mutton suet, which are too hard for satisfactory use in shortening, may be softened to the desired consistency by mixing softer fats like lard or cottonseed oil with them. The follow-

¹ U. S. Dept. Agr., Farmers' Bul. 526 (1915), p. 9.

ing recipes have been found to be satisfactory in preparing a soft culinary fat from these hard fats:

SOFT FAT, I.

Grind together two parts unrendered beef or mutton fat and one part lard. Render in double boiler as described on page 22.

This fat is improved by adding $\frac{1}{2}$ pint of milk to each 2 pounds of the mixture before rendering. The flavor is thus improved, and the fat may be used for frying or shortening.

SOFT FAT, II.

Mix three parts unrendered beef or mutton fat (ground fine) and one part refined cottonseed oil. Render in double boiler as described on page 22.

Rendered beef or mutton fats may be softened by adding to them the lard or cottonseed oil, heating the mixture until melted, and mixing thoroughly. It is desirable to stir these mixed fats occasionally while cooling to avoid the danger of the hard fat separating out. The beef and mutton flavors are lessened somewhat by this softening process.

CARE AND STORAGE OF FATS IN THE HOME.

The chief precaution to be taken in storing fats is to prevent them from becoming rancid. The exact nature of the chemical changes undergone by fats when they become rancid is not definitely known. It is certain, however, that rancidity does not occur without the previous formation of free fatty acids, and for the formation of fatty acids light, heat, and air (containing oxygen) are necessary. Therefore, fats to be stored for some time should be protected from heat, light, and air. In the case of table fats like butter, which usually are not kept long in the home, it is only necessary to keep them in a cool place and away from objectionable odors and flavors, which they absorb quite readily. The common custom of keeping butter in a clean earthen dish in the ice compartment of the refrigerator is probably the most satisfactory for the average housewife. The rural custom of keeping it in a pail suspended in a deep well or on a cool and dry, clean cellar bottom is also satisfactory. Table oil, from which small quantities are used frequently, keeps best if stored in a cool place like a refrigerator and kept in small closed containers so as to exclude the air as much as possible. Bottles of dark glass, or wrapped in light-proof paper, have an advantage over clear glass bottles in that they exclude the light. Tin cans are also very satisfactory for this purpose.

More care is necessary in the storage of cooking fats than is the case with table fats, because the former are generally purchased in larger quantities and are kept longer. While it is not necessary to

seal these fats as tightly as is the case with canned fruits, they should, nevertheless, always be kept in covered receptacles and in a cool, dark place. Also, fats like lard should contain (or more accurately inclose) very little moisture, since this favors the growth of molds. In warm weather scraps of fat to be saved should be rendered promptly to prevent them from becoming rancid. In cold weather they may be kept until a sufficient quantity has accumulated to make rendering worth while.

SUMMARY.

Economy of fats in the home may be secured by intelligent selection, economical use, and by the prevention of unnecessary waste. For intelligent selection, which means choosing the fat best suited for the purpose in question, a knowledge of the properties and prices of the different fats on the market is necessary. It should be remembered that the energy value of all the pure fats is practically the same, and the housekeeper must determine how much she can afford to pay for particular flavors or appearance, on which the difference in price largely depends. To secure economy fats should be used primarily for the purposes to which they are best adapted, and the extravagant use of both table and cooking fats should be avoided. To prevent unnecessary waste fats should be carefully handled and stored so that none need be discarded through spoilage. Furthermore, all scraps of fat which accumulate in the home should be saved and used for culinary purposes wherever possible, thus lessening the amount of money expended for cooking fats. It should always be borne in mind that while an economical use of fat is to be desired, stinting is to be avoided. In determining how far economy in the use of fats is to be practiced one should bear in mind that true economy is possible only where the value of the time and energy involved in the saving or utilizing of an article is less than the value of the articles saved.

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PROFESSIONAL PAPER

December 22, 1916

STUDIES ON THE DIGESTIBILITY OF THE GRAIN SORGHUMS.

By C. F. LANGWORTHY, *Chief*, and A. D. HOLMES, *Scientific Assistant, Office of Home Economics.*

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INTRODUCTION.

As the result of many attempts to find crops suitable for cultivation in the semiarid regions of the Western States of this country, the non-saccharine grain sorghums have been successfully introduced from South Africa, where they have for a long time held a prominent place as a staple cereal crop. In India, China, and other oriental countries the sorghums have been used in both animal and human nutrition, oftentimes comprising the major portion of the available supply of food suitable for human consumption. As an instance of their importance, Lapique¹ states that the dietary of the Abyssinians is essentially a vegetarian one composed largely of durra (*Sorghum vulgare*). In an exploring expedition through China Meyer² observed that one of the sorghums, kaoliang, was extensively used for human food. In some localities it was prepared as a mush and eaten by the very poor coolies with such condiments as gingerroot, garlic, and radishes. By people slightly better off this sorghum was ground into a meal and made into a bread. In both instances Meyer observed that exceptionally large quantities of the grain were consumed, making an even more bulky diet than most strictly

¹ Compt. Rend. Soc. Biol. [Paris], 5 (1893), No. 9, pp. 251-258.

² Personal communication.

vegetarian diets, and he believed accordingly that kaoliang was very incompletely utilized by the human system.

In this country feterita, kafir, dwarf milo, and kaoliang are well-known varieties of the grain sorghums which have for some time been used primarily as feeding crops for animals, but which in some instances have formed a part of the human dietary. The people living in those sections of the country where the sorghums have been grown have long known that these grains are suitable for use as food, and the agricultural press has from time to time reported successful attempts to use them for this purpose. Moreover, following the introduction of the sorghums into the agriculture of the United States, commercial attempts have been made to interest the public in these grains for bread making and similar uses.

Numerous tests of these grains have been made to determine their composition and nutritive value as a feeding crop for animals and, in some instances, to learn how they may best be prepared for human consumption. Many baking tests, for example, have been made with the meal of kafir, which is perhaps the best known of the sorghums, to determine whether it can be used more advantageously alone or mixed with some other meal in ordinary baking practices. The Department of Agriculture¹ has studied the preparation and uses of kafir meal, reporting a number of recipes for incorporating it in such common foods as bread, doughnuts, cookies, etc. A series of baking tests described by Dillon² indicates that kafir meal in admixture with wheat flour in the proportion of 1 to 1, 1 to 2, or 2 to 1, makes a very satisfactory bread. Francis³ reports analyses comparing the composition and food value of feterita, Indian corn, kafir, and wheat, and gives recipes for the preparation of bread and similar products, using part feterita meal and part wheat flour. He concludes that feterita resembles corn in composition, having a nutritive value of about 90 per cent of that of corn, and suggests, moreover, that feterita, being somewhat softer than kafir, should be more thoroughly digested. General information and a number of tested recipes compiled from various sources are given by Davis⁴ regarding the value of kafir, feterita, and milo as cereal foods. Summers⁵ reports comparative analyses of feterita and wheat together with the results of a series of baking tests. He found that the best bread, pancakes, or gems, could be made by using 50 per cent of feterita meal and 50 per cent of wheat flour. Similar studies of kaoliang are reported by Fromme⁶, who used kaoliang meal in place of kafir meal in the recipes reported by the Office of Home Economics.

¹ U. S. Dept. Agr., Farmers' Bul. 559 (1913), pp. 6, 7.

² Northwest. Miller, 90 (1912), No. 2, pp. 79, 80.

³ Oklahoma Sta. Circ. 27 (1914), pp. 8.

⁴ Texas Dept. Agr. Bul. 42 (1915), p. 18.

⁵ Oper. Miller, 20 (1915), No. 1, pp. 42-44.

⁶ South Dakota Agr. Expt. Sta. Bul. 158 (1915), pp. 170-174.

The results of these investigations as a whole indicate that while it is best to use some wheat flour to make up for the lack of gluten in the sorghum meal a fairly large proportion of the meal may be satisfactorily used in admixture with wheat flour in the preparation of common foods.

According to Davis¹ it has been noted that dwarf kafir will pop like pop corn. Tests made in connection with the work of the department showed that this was true of dwarf kafir and of feterita and dwarf milo as well, while kaoliang, it was found, scorched without popping. The kafir when popped was tender and of good flavor, closely resembling ordinary pop corn in miniature. Fewer kernels of feterita and dwarf milo popped, and the taste of these, moreover, was comparatively raw and less agreeable than that of the kafir. The kaoliang became quite crisp and tender without popping and had an agreeable taste. It should be noted in trying to pop the sorghums that, owing to the small size of the grain, the popper should be lined with wire netting to prevent its falling through. In similar tests with some of the millets no noticeable success was obtained in trying to pop the grains.

Since a survey of the literature indicates that while digestion experiments with animals are fairly common, few if any studies with man have been reported, it seemed desirable to determine experimentally the digestibility of the grain sorghums, preparing them in different ways for eating, in order to secure data as to their value in human nutrition.

MILLING THE GRAIN SORGHUMS.

Realizing that considerable differences in the chemical composition of any grain occur as a result of variations in climatic and soil conditions, an attempt was made to obtain a supply of the different grains grown under identically the same conditions, and through the cooperation of the Bureau of Plant Industry standardized grain was secured from the cereal field station at Amarillo, Tex. All the grains, including the corn and wheat which were used for comparison, were milled in the Bureau of Chemistry, the same mill being used for each grain and especial care exercised to secure meals of the same fineness. Milled in this way, the product in each case more nearly resembled meal than flour; consequently "meal" will be the descriptive term used throughout this discussion. A record was kept of the proportions of the different grains passing through the 16, 20, 40, 70, and 109 mesh sieves, but only that portion of the meal which passed through the 16-mesh sieve (that is, the size of sieve commonly used by the housekeeper) was used in the preparation of the experimental diet. The amount of kafir bran retained on the sieve and considered too coarse to use in the digestion experiments was about 21 per cent

¹ Texas Dept. Agr. Bul. 42 (1915), pp. 18.

of the total. In the case of the other grain sorghums the values were, milo, 19 per cent; feterita, 15 per cent; and kaoliang, 5 per cent. That these different proportions of the four meals prepared in the same mill should be obtained under similar conditions is most likely due to the structure of the grain, for, although the break was made in the same way, the different grains did not fracture evenly along the same lines. The protein content of the meal, which depends partly upon the quantity of bran removed in the process of milling, was proportionately less in the kafir and milo meals than in the others, since more bran was removed from them on the sieve.

COOKING TESTS AND THE EXPERIMENTAL DIETS.

Before deciding upon the experimental diet a series of tests was undertaken to determine a good method of preparing the sorghum meals for eating and also a suitable combination of foods to serve as a basal ration in the digestion experiments. Results previously reported from the Office¹ of Home Economics indicated that dwarf kafir requires a more thorough cooking than is customary for Indian corn, and that it is often desirable to make a mush of the meal as a foundation for other dishes (yeast bread, gingerbread, etc.). In view of this experience, a mush was first made of one of the sorghum meals (kafir) by cooking 3 cups of meal, 3 cups of water, a little salt, and 3 tablespoonfuls of lard for a half-hour in a double boiler. The lard was simply placed on top of the other ingredients, not mixed with them, for it was noted that when the lard melted it floated on top and prevented excessive evaporation. Baking powder was then beaten into the mush and the bread was baked, but because of the lack of gluten in the kafir meal difficulty was experienced in making such bread light. The addition of glutinous flours, eggs, milk, or other substances containing protein was not desirable, for it was recognized that the presence of protein from any other source than the sorghum grain would complicate the problem of determining the digestibility of the grain protein. It was found, however, that by the above method suitable bread resembling corn bread could be made, providing the batter was baked in a very thin layer. Owing to the loss of practically all the water originally present the bread was extremely dry, hard, and crusty and contained practically no crumb. It was used only in the first series of experiments with kafir meal, when this sorghum was eaten with a basal ration containing only milk, fruit (oranges), and a little sugar to make the diet palatable.

The experience gained in these and earlier cooking tests made it evident that in order to cook the grain sorghums thoroughly a preliminary softening by boiling is desirable, or else it is necessary to have sufficient water present to soften the grain during the baking

¹ U. S. Dept. Agr. Farmer's Bul. 559 (1913), pp. 6, 7.

and to prevent the drying out and hardening of the loaf. In most of the digestion experiments with the sorghum breads, accordingly, the bread was made by the following recipe, which it will be noted contains ginger added to make the bread more palatable:

SORGHUM BREAD.

| | |
|--------------------|-------------------------------|
| 15 cups meal. | 3½ teaspoons salt. |
| 3½ teaspoons soda. | 5 teaspoons ginger. |
| 1½ cups molasses. | 1 scant cup lard (melted in). |

1½ quarts hot water (added to above mixture).

In this series of tests the bread was baked about 1½ hours, without preliminary cooking in the double boiler. The loss of water by evaporation usually caused it to lose from one-fifth to one-sixth of its original weight, but moisture enough remained after the baking to give a bread composed almost entirely of crumb and sufficiently moist to be palatable. Although the bread contained no glutinous material as a binder and tended to crumble when hot, it could easily be cut without much crumbling when cold. Six similar lots of bread were prepared from dwarf kafir, feterita, dwarf milo, kaoliang, corn, and wheat meals, and eaten as a part of a simple mixed diet. The basal ration was composed of apple sauce, potatoes, and butter and furnished only a small fraction of all the protein in the diet, namely, about 20 per cent, which was derived very largely from the potatoes. Although theoretically it would have been even better to eliminate all protein from the basal ration in order to make possible an absolutely direct determination of the digestibility of true grain protein, it was not considered practicable to make use of a protein-free basal ration in these experiments, as such a diet would not have been palatable.

Since it seemed desirable to determine whether the method of preparing the meals for eating materially influenced their digestibility, experiments were also made with the sorghums cooked in the form of a mush. It was found that a satisfactory mush could be prepared in the usual household way as follows: About 15 cups of meal, with salt for seasoning, were mixed with somewhat more boiling water than could be absorbed, and this was cooked for three to four hours in a double boiler which kept the temperature of the mush just below the boiling point for the entire cooking period. The basal ration eaten with the mushes in the digestion experiments consisted of apple sauce, butter, and a cane-sugar sirup—essentially the same ingredients as were used in the experiments with the different kinds of bread. By omitting the potatoes from the ration, however, the amount of protein from accessory foods was greatly reduced, so that 98 to 99 per cent of the total protein consumed was supplied by the grain protein.

SUBJECTS OF THE EXPERIMENTS.

The seven subjects who assisted in the digestion experiments had acquired experience in work of this kind from the tests conducted in the Office of Home Economics with animal fats.¹ They were young men of medium weight and of good health, capable of following instructions carefully, and well informed as to the details and conditions of the experiments. As usual in work of this kind, they were informed that regularity in all of their daily habits was highly desirable. No prescribed hour for eating or regular exercise other than that ordinarily obtained in pursuance of their daily routine was required.

METHODS OF PROCEDURE.

The methods employed closely resembled those tested and found satisfactory in the experiments with the fats. In order to obtain a uniform product the ingredients of the breads and mushes were thoroughly mixed, and care was taken to maintain a constant temperature during the cooking process. In each instance sufficient material was prepared at one time to supply all the subjects for the entire test period. The quantity of the bread or mush eaten was not restricted nor were any of the other components of the diet limited except the potato. In the diets of which the latter formed a part it was given in restricted quantities, so that the potato protein should not form too large a proportion of the total protein content of the diet.

No attention was paid to the maintenance of nitrogen equilibrium, nor were collections and analyses of the urine made to determine what percentage of energy, owing to the occurrence of incompletely oxidized nitrogen in the urine, was not available. Factors based on the results of earlier work were used to estimate indirectly the amount of energy actually available to the body. A record of body weights was not kept, for the purpose of the investigation was primarily the determination of the coefficients of digestibility of the grain sorghums. The 3-day or 9-meal period was judged to be of sufficient duration to permit of accurate analytical results, and since the ration was made up to resemble closely the ordinary mixed diet, preliminary and final periods were omitted.

All analyses were made according to the methods outlined by the Association of Official Agricultural Chemists.² Separation of the feces of a test period was accomplished by the use of charcoal taken in gelatin capsules with the first meal of the experiment and with the first meal succeeding the 3-day period. Samples of the bread and of the air-dried feces were analyzed, but the composition of the potato, apple sauce, and butter was estimated by comparison with the average values of a large number of earlier analyses.³ Allowances were made

¹ U. S. Dept. Agr. Bul. 310 (1915).

² U. S. Dept. Agr., Office Expt. Stas. Bul. 28 (1906).

³ U. S. Dept. Agr., Bur. Chem. Bul. 107 (1912).

for changes in the composition of the apples and potatoes taking place during the preparation for eating.

The two common methods for determining the coefficients of digestibility of any single food contained in a mixed diet are, applying the factors obtained in a direct determination of the availability of the basal ration (digestion experiments with the basal ration alone), and using factors for the digestibility of the basal ration which were determined by averaging the results of earlier experimental data. In the experiments reported in this paper the latter method was used. The digestibility of the bread alone was estimated by assuming the following values for the digestibility of the accessory food materials: The protein of potatoes, 83 per cent; the protein of milk and butter, 97 per cent; the protein of fruit, 85 per cent; the carbohydrate of potatoes, 95 per cent; and the carbohydrate of milk and cane sugar, 98 per cent. These assumed values are not absolute, but are close approximations based on the results of a large amount of reliable experimental work.¹

The method of estimating the digestibility of the bread alone is indicated by the following equations:

[Weight of protein in accessory food materials] $\times$ [Percentage of undigested protein in each] = [Protein in feces from food other than bread.

[Total protein in feces] - [Protein in feces from food other than bread] = [Weight of undigested bread protein.]

[Weight of protein in bread] - [Weight of undigested bread protein] $\div$ [Weight of protein in bread] = [Estimated percentage of availability of bread protein.] This value, and a similarly computed one for the digestibility of the bread carbohydrate, are given in the tables and are taken as the coefficients of availability of the protein and carbohydrate in the grains. Since the quantity of lard used in making the bread was greatly in excess of the fat content of the grain, it seemed relatively unimportant to estimate the digestibility of the fat of the grain. In view of the fact that the diet contained accessory foods supplying considerable quantities of both carbohydrate and fat, the digestibility of these constituents from the total diet should be approximately the same as has been found for the ordinary mixed diet,² namely, 97 and 95 per cent.

DIGESTIBILITY OF THE SORGHUM MEALS PREPARED AS BREADS.

DIGESTION EXPERIMENTS WITH HARD KAFIR BREAD.

The first series of tests with kafir bread included seven 3-day experiments with four different subjects. The bread formed a part of a simple mixed diet containing milk, fruit (oranges), and sugar. As noted on page 4, this bread was thin and had thick, hard crusts

¹ Connecticut Storrs Sta. Rpt. 1899, p. 104.

² Connecticut Storrs Sta. Rpt. 1901, p. 245.

but practically no crumb, and since it proved to be rather brittle and tasteless, such bread was not used in the studies with the other sorghums. The data of the experiments are given in the following tables:

Data of digestion experiments with hard kafir bread in a simple mixed diet containing milk.

| | Weight. | Water. | Protein. | Fat. | Carbohydrates. | Ash. |
|---|---------------|---------------|---------------|---------------|----------------|---------------|
| Experiment No. 89, subject R. L. S.: | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> |
| Kafir bread | 1,447.1 | 292.0 | 146.6 | 144.7 | 842.9 | 20.9 |
| Milk | 4,326.8 | 3,764.3 | 142.8 | 173.1 | 216.3 | 30.3 |
| Orange | 333.5 | 289.8 | 2.7 | .7 | 38.7 | 1.6 |
| Sugar | 33.9 | | | | 33.9 | |
| Total food consumed | 6,141.3 | 4,346.1 | 292.1 | 318.5 | 1,131.8 | 52.8 |
| Feces | 102.9 | | 39.9 | 20.4 | 26.9 | 15.7 |
| Amount utilized | | | 252.2 | 298.1 | 1,104.9 | 37.1 |
| Digestibility of entire ration (per cent) | | | 86.3 | 93.6 | 97.6 | 70.3 |
| Estimated digestibility of bread alone (per cent) | | | 76.0 | | 97.9 | |
| Experiment No. 90, subject I. D. B.: | | | | | | |
| Kafir bread | 1,177.5 | 237.6 | 119.3 | 117.7 | 685.9 | 17.0 |
| Milk | 4,309.3 | 3,749.1 | 142.2 | 172.4 | 215.4 | 30.2 |
| Orange | 1,289.4 | 1,120.5 | 10.3 | 2.6 | 149.6 | 6.4 |
| Sugar | 201.7 | | | | 201.7 | |
| Total food consumed | 6,977.9 | 5,107.2 | 271.8 | 292.7 | 1,252.6 | 53.6 |
| Feces | 161.8 | | 73.2 | 24.6 | 45.9 | 18.1 |
| Amount utilized | | | 198.6 | 268.1 | 1,206.7 | 35.5 |
| Digestibility of entire ration (per cent) | | | 73.1 | 91.6 | 96.3 | 66.2 |
| Estimated digestibility of bread alone (per cent) | | | 43.5 | | 96.7 | |
| Experiment No. 91, subject W. D.: | | | | | | |
| Kafir bread | 914.6 | 184.6 | 92.6 | 91.5 | 532.7 | 13.2 |
| Milk | 4,335.3 | 3,771.7 | 143.1 | 173.4 | 216.8 | 30.3 |
| Orange | 1,389.3 | 1,207.3 | 11.1 | 2.8 | 161.2 | 6.9 |
| Sugar | | | | | | |
| Total food consumed | 6,639.2 | 5,163.6 | 246.8 | 267.7 | 910.7 | 50.4 |
| Feces | 102.7 | | 38.0 | 20.0 | 28.1 | 16.6 |
| Amount utilized | | | 208.8 | 247.7 | 882.6 | 33.8 |
| Digestibility of entire ration (per cent) | | | 84.6 | 92.5 | 96.9 | 67.1 |
| Estimated digestibility of bread alone (per cent) | | | 65.4 | | 98.6 | |
| Experiment No. 92, subject E. E. M.: | | | | | | |
| Kafir bread | 1,135.2 | 229.1 | 115.0 | 113.5 | 661.2 | 16.4 |
| Milk | 4,294.0 | 3,735.8 | 141.7 | 171.8 | 214.7 | 30.0 |
| Orange | 1,515.6 | 1,317.1 | 12.1 | 3.0 | 175.8 | 7.6 |
| Sugar | 195.2 | | | | 195.2 | |
| Total food consumed | 7,140.0 | 5,282.0 | 268.8 | 288.3 | 1,246.9 | 54.0 |
| Feces | 124.6 | | 57.0 | 15.8 | 34.5 | 17.3 |
| Amount utilized | | | 211.8 | 272.5 | 1,212.4 | 36.7 |
| Digestibility of entire ration (per cent) | | | 78.8 | 94.5 | 97.2 | 68.0 |
| Estimated digestibility of bread alone (per cent) | | | 55.7 | | 98.7 | |
| Experiment No. 98, subject I. D. B.: | | | | | | |
| Kafir bread | 1,307.3 | 164.7 | 152.9 | 320.3 | 643.2 | 26.2 |
| Milk | 4,305.3 | 3,745.6 | 142.1 | 172.2 | 215.3 | 30.1 |
| Orange | 1,466.5 | 1,274.4 | 11.7 | 3.0 | 170.1 | 7.3 |
| Sugar | 207.8 | | | | 207.8 | |
| Total food consumed | 7,286.9 | 5,184.7 | 306.7 | 495.5 | 1,236.4 | 63.6 |
| Feces | 181.8 | | 93.2 | 26.2 | 43.3 | 19.1 |
| Amount utilized | | | 213.5 | 469.3 | 1,193.1 | 44.5 |
| Digestibility of entire ration (per cent) | | | 69.6 | 94.7 | 96.5 | 70.0 |
| Estimated digestibility of bread alone (per cent) | | | 43.0 | | 97.2 | |

Data of digestion experiments with hard kafir bread in a simple mixed diet containing milk—Continued.

| | Weight. | Water. | Protein. | Fat. | Carbohy-
drates. | Ash. |
|---|---------------|---------------|---------------|---------------|---------------------|---------------|
| Experiment No. 99, subject W. D.: | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> |
| Kafir bread..... | 798.3 | 100.6 | 93.4 | 195.6 | 392.7 | 16.0 |
| Milk..... | 4,320.6 | 3,758.9 | 142.6 | 172.8 | 216.0 | 30.3 |
| Orange..... | 1,459.4 | 1,268.2 | 11.7 | 2.9 | 169.4 | 7.2 |
| Sugar..... | | | | | | |
| Total food consumed..... | 6,578.3 | 5,127.7 | 247.7 | 371.3 | 778.1 | 53.5 |
| Feces..... | 106.8 | | 36.5 | 23.0 | 29.3 | 18.0 |
| Amount utilized..... | | | 211.2 | 348.3 | 748.8 | 35.5 |
| Digestibility of entire ration (per cent)..... | | | 85.3 | 93.8 | 96.2 | 66.4 |
| Estimated digestibility of bread alone
(per cent)..... | | | 67.5 | | 97.9 | |
| Experiment No. 100, subject E. E. M.: | | | | | | |
| Kafir bread..... | 1,032.6 | 130.1 | 120.8 | 253.0 | 508.0 | 20.7 |
| Milk..... | 4,314.0 | 3,753.2 | 142.3 | 172.6 | 215.7 | 30.2 |
| Orange..... | 1,471.7 | 1,278.9 | 11.8 | 2.9 | 170.7 | 7.4 |
| Sugar..... | 173.4 | | | | 173.4 | |
| Total food consumed..... | 6,991.7 | 5,162.2 | 274.9 | 428.5 | 1,067.8 | 58.3 |
| Feces..... | 133.3 | | 54.8 | 20.4 | 37.8 | 20.3 |
| Amount utilized..... | | | 220.1 | 408.1 | 1,030.0 | 38.0 |
| Digestibility of entire ration (per cent)..... | | | 80.1 | 95.2 | 96.5 | 65.2 |
| Estimated digestibility of bread alone
(per cent)..... | | | 59.7 | | 97.5 | |
| Average food consumed per subject
per day..... | 2,274.1 | 1,684.4 | 90.9 | 117.3 | 363.1 | 18.4 |

Summary of digestion experiments with hard kafir bread in a simple mixed diet containing milk.

| Experi-
ment No. | Subject. | Protein. | Carbohy-
drates. | Experi-
ment No. | Subject. | Protein. | Carbohy-
drates. |
|---------------------|--------------|------------------|---------------------|---------------------|--------------|------------------|---------------------|
| | | <i>Per cent.</i> | <i>Per cent.</i> | | | <i>Per cent.</i> | <i>Per cent.</i> |
| 89..... | R. L. S..... | 76.0 | 97.9 | 99..... | W. D..... | 67.5 | 97.9 |
| 90..... | I. D. B..... | 43.5 | 96.7 | 100..... | E. E. M..... | 59.7 | 97.5 |
| 91..... | W. D..... | 65.4 | 98.6 | | Average..... | 58.7 | 97.8 |
| 92..... | E. E. M..... | 55.7 | 98.7 | | | | |
| 98..... | I. D. B..... | 43.0 | 97.2 | | | | |

As indicated in the summary table, the average estimated values for the digestibility of kafir bread alone were 58.7 per cent for the protein and 97.8 per cent for the carbohydrate. The bread supplied an average of 40 grams of protein and 203 grams of carbohydrate daily. The usual figures for the percentage of digestibility of the nutrients of cereals are 85 per cent for protein, 90 per cent for fat, and 98 per cent for carbohydrates.¹ On the whole, these experiments and those that follow indicate that the carbohydrate of the grain sorghums is practically as completely utilized for food as can be expected with any cereal product, but that the grain protein is very incompletely digested. In the comparative experiments which follow the bread was prepared by a different recipe.

¹ Connecticut Storrs Sta. Rpt. 1899, p. 194.

DIGESTION EXPERIMENTS WITH SOFTER KAFIR BREAD.

In the second series of tests with dwarf kafir a gingerbread made by the recipe on page 5 was eaten with a basal ration containing potatoes, apple sauce, butter, and sugar. Since the ration contained no milk, it supplied considerably less protein than was furnished in the preceding experiments; and the diet proved so satisfactory that bread was made in the same way for use in the tests with the other sorghums and in the experiments with corn and wheat meals which were made for the purpose of comparison. The data of the experiments with kafir bread are reported in the following tables:

Data of digestion experiments with softer kafir bread in a simple mixed diet.

| | Weight. | Water. | Protein. | Fat. | Carbohy-
drates. | Ash. |
|---|---------------|---------------|---------------|---------------|---------------------|---------------|
| Experiment No. 187, subject D. G. G.: | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> |
| Kafir bread | 1,470.0 | 512.1 | 105.7 | 93.5 | 719.7 | 39.0 |
| Potato | 917.0 | 687.7 | 27.5 | | 192.6 | 9.2 |
| Apple sauce | 1,165.0 | 1,048.5 | 3.5 | 3.5 | 107.2 | 2.3 |
| Butter | 351.0 | 38.6 | 3.5 | 298.4 | | 10.5 |
| Sugar | 199.0 | | | | 199.0 | |
| Total food consumed | 4,102.0 | 2,286.9 | 140.2 | 395.4 | 1,218.5 | 61.0 |
| Feces | 45.0 | | 19.8 | 4.2 | 16.2 | 4.8 |
| Amount utilized | | | 120.4 | 391.2 | 1,202.3 | 56.2 |
| Digestibility of entire ration (per cent) | | | 85.9 | 98.9 | 98.7 | 92.1 |
| Estimated digestibility of bread alone (per cent) | | | 90.8 | | 98.7 | |
| Experiment No. 188, subject R. L. S.: | | | | | | |
| Kafir bread | 1,191.0 | 414.9 | 85.6 | 75.8 | 583.1 | 31.6 |
| Potato | 792.0 | 594.0 | 23.8 | | 166.3 | 7.9 |
| Apple sauce | 1,108.0 | 997.2 | 3.3 | 3.3 | 101.9 | 2.3 |
| Butter | 233.0 | 25.6 | 2.3 | 198.1 | | 7.0 |
| Sugar | 157.0 | | | | 157.0 | |
| Total food consumed | 3,481.0 | 2,031.7 | 115.0 | 277.2 | 1,008.3 | 48.8 |
| Feces | 144.0 | | 62.2 | 14.1 | 53.2 | 14.5 |
| Amount utilized | | | 52.8 | 263.1 | 955.1 | 34.3 |
| Digestibility of entire ration (per cent) | | | 45.9 | 94.7 | 94.7 | 70.3 |
| Estimated digestibility of bread alone (per cent) | | | 38.0 | | 94.6 | |
| Experiment No. 189, subject O. E. S.: | | | | | | |
| Kafir bread | 1,325.0 | 461.6 | 95.3 | 84.3 | 648.7 | 35.1 |
| Potato | 839.0 | 629.2 | 25.2 | | 176.2 | 8.4 |
| Apple sauce | 1,113.0 | 1,001.7 | 3.3 | 3.4 | 102.4 | 2.2 |
| Butter | 278.0 | 30.6 | 2.8 | 236.3 | | 8.3 |
| Sugar | 192.0 | | | | 192.0 | |
| Total food consumed | 3,747.0 | 2,123.1 | 126.6 | 324.0 | 1,119.3 | 54.0 |
| Feces | 164.0 | | 68.3 | 15.7 | 64.6 | 15.4 |
| Amount utilized | | | 58.3 | 308.3 | 1,054.7 | 38.6 |
| Digestibility of entire ration (per cent) | | | 46.0 | 95.2 | 94.2 | 71.5 |
| Estimated digestibility of bread alone (per cent) | | | 38.2 | | 93.6 | |
| Experiment No. 190, subject R. F. T.: | | | | | | |
| Kafir bread | 1,018.0 | 354.7 | 73.2 | 64.7 | 498.4 | 27.0 |
| Potato | 547.0 | 410.2 | 16.4 | | 114.9 | 5.5 |
| Apple sauce | 1,235.0 | 1,111.5 | 3.7 | 3.7 | 113.6 | 2.5 |
| Butter | 168.0 | 18.5 | 1.7 | 142.8 | | 5.0 |
| Sugar | 179.0 | | | | 179.0 | |
| Total food consumed | 3,147.0 | 1,894.9 | 95.0 | 211.2 | 905.9 | 40.0 |
| Feces | 134.5 | | 54.3 | 20.7 | 45.0 | 14.5 |
| Amount utilized | | | 40.7 | 190.5 | 860.9 | 25.5 |
| Digestibility of entire ration (per cent) | | | 42.8 | 90.2 | 95.0 | 63.7 |
| Estimated digestibility of bread alone (per cent) | | | 37.4 | | 95.1 | |

Data of digestion experiments with softer kafir bread in a simple mixed diet—Continued.

| | Weight. | Water. | Protein. | Fat. | Carbohy-
drates. | Ash. |
|---|---------------|---------------|---------------|---------------|---------------------|---------------|
| Experiment No. 211, subject D. G. G.: | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> |
| Kafir bread..... | 1,736.0 | 583.3 | 139.9 | 96.4 | 871.8 | 44.6 |
| Potato..... | 1,008.0 | 756.0 | 30.2 | ----- | 211.7 | 10.1 |
| Apple sauce..... | 798.0 | 718.2 | 2.4 | 2.4 | 73.4 | 1.6 |
| Butter..... | 330.0 | 36.3 | 3.3 | 280.5 | ----- | 9.9 |
| Sugar..... | 201.0 | ----- | ----- | ----- | 201.0 | ----- |
| Total food consumed..... | 4,073.0 | 2,093.8 | 175.8 | 379.3 | 1,357.9 | 66.2 |
| Feces..... | 135.0 | ----- | 66.2 | 9.8 | 33.0 | 26.0 |
| Amount utilized..... | ----- | ----- | 109.6 | 369.5 | 1,324.9 | 40.2 |
| Digestibility of entire ration (per cent)..... | ----- | ----- | 62.3 | 97.4 | 97.6 | 60.7 |
| Estimated digestibility of bread alone
(per cent)..... | ----- | ----- | 59.0 | ----- | 98.7 | ----- |
| Experiment No. 212, subject R. L. S.: | | | | | | |
| Kafir bread..... | 1,354.0 | 454.9 | 109.1 | 75.2 | 680.0 | 34.8 |
| Potato..... | 753.0 | 564.8 | 22.6 | ----- | 158.1 | 7.5 |
| Apple sauce..... | 1,122.0 | 1,009.8 | 3.4 | 3.4 | 103.2 | 2.2 |
| Butter..... | 209.0 | 23.0 | 2.1 | 177.6 | ----- | 6.3 |
| Sugar..... | 182.0 | ----- | ----- | ----- | 182.0 | ----- |
| Total food consumed..... | 3,620.0 | 2,052.5 | 137.2 | 256.2 | 1,123.3 | 50.8 |
| Feces..... | 136.0 | ----- | 63.0 | 18.1 | 40.6 | 14.3 |
| Amount utilized..... | ----- | ----- | 74.2 | 238.1 | 1,082.7 | 36.5 |
| Digestibility of entire ration (per cent)..... | ----- | ----- | 54.1 | 92.9 | 96.4 | 71.9 |
| Estimated digestibility of bread alone
(per cent)..... | ----- | ----- | 50.5 | ----- | 97.2 | ----- |
| Experiment No. 213, subject O. E. S.: | | | | | | |
| Kafir bread..... | 1,631.0 | 548.0 | 131.5 | 90.5 | 819.1 | 41.9 |
| Potato..... | 974.0 | 730.5 | 29.2 | ----- | 204.5 | 9.8 |
| Apple sauce..... | 1,145.0 | 1,030.5 | 3.4 | 3.5 | 105.3 | 2.3 |
| Butter..... | 280.0 | 30.8 | 2.8 | 238.0 | ----- | 8.4 |
| Sugar..... | 227.0 | ----- | ----- | ----- | 227.0 | ----- |
| Total food consumed..... | 4,257.0 | 2,339.8 | 166.9 | 332.0 | 1,355.9 | 62.4 |
| Feces..... | 193.0 | ----- | 83.6 | 22.5 | 66.3 | 20.6 |
| Amount utilized..... | ----- | ----- | 83.3 | 309.5 | 1,289.6 | 41.8 |
| Digestibility of entire ration (per cent)..... | ----- | ----- | 49.9 | 93.2 | 95.1 | 67.0 |
| Estimated digestibility of bread alone
(per cent)..... | ----- | ----- | 44.2 | ----- | 95.0 | ----- |
| Average food consumed per subject
per day..... | 1,258.4 | 705.8 | 45.6 | 103.6 | 385.2 | 18.2 |

Summary of digestion experiments with softer kafir bread in a simple mixed diet.

| Experi-
ment
No. | Subject. | Protein. | Carbohy-
drates. | Experi-
ment
No. | Subject. | Protein. | Carbohy-
drates. |
|------------------------|--------------|------------------|---------------------|------------------------|--------------|------------------|---------------------|
| | | <i>Per cent.</i> | <i>Per cent.</i> | | | <i>Per cent.</i> | <i>Per cent.</i> |
| 187..... | D. G. G..... | 90.8 | 98.7 | 212..... | R. L. S..... | 50.5 | 97.2 |
| 188..... | R. L. S..... | 38.0 | 94.6 | 213..... | O. E. S..... | 44.2 | 95.0 |
| 189..... | O. E. S..... | 38.2 | 93.6 | | | | |
| 190..... | R. F. T..... | 37.4 | 95.1 | | Average..... | 51.2 | 96.1 |
| 211..... | D. G. G..... | 59.0 | 98.7 | | | | |

In these experiments with the softer kafir bread in a simple mixed diet it will be noted that on an average 46 grams of protein and 385 grams of carbohydrate were supplied the subjects daily. The bread alone furnished 35 grams and 230 grams of these constituents, which were found to be 51.2 per cent and 96.1 per cent digested, respectively. These figures indicate that the bread protein apparently was less available than in the preceding tests in which harder kafir bread was eaten with milk.

DIGESTION EXPERIMENTS WITH FETERITA BREAD.

Feterita was also used in the form of a bread flavored with ginger, experience having shown that all such gingerbreads, owing to their slightly sweet and spicy flavor, are very appetizing. For example, the subjects ate an average of eight-tenths of a pound of the feterita bread per day and over a pound of the kafir bread which was made according to the same recipe. The data of the digestion experiments with feterita bread eaten with a simple mixed diet follow:

Data of digestion experiments with feterita bread in a simple mixed diet.

| | Weight. | Water. | Protein. | Fat. | Carbohy-
drates. | Ash. |
|---|---------------|---------------|---------------|---------------|---------------------|---------------|
| Experiment No. 195, subject D. G. G.: | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> |
| Feterita bread..... | 1,422.0 | 477.9 | 113.4 | 82.2 | 705.6 | 42.9 |
| Potato..... | 918.0 | 688.5 | 27.5 | ..... | 192.8 | 9.2 |
| Apple sauce..... | 888.0 | 799.2 | 2.7 | 2.6 | 81.7 | 1.8 |
| Butter..... | 268.0 | 29.5 | 2.7 | 227.8 | ..... | 8.0 |
| Sugar..... | 137.0 | ..... | ..... | ..... | 137.0 | ..... |
| Total food consumed..... | 3,633.0 | 1,995.1 | 146.3 | 312.6 | 1,117.1 | 61.9 |
| Feces..... | 124.0 | ..... | 62.2 | 14.5 | 34.9 | 12.4 |
| Amount utilized..... | ..... | ..... | 84.1 | 298.1 | 1,082.2 | 49.5 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 57.5 | 95.4 | 96.9 | 80.0 |
| Estimated digestibility of bread
alone (per cent)..... | | | 52.9 | | 98.0 | |
| Experiment No. 196, subject R. L. S.: | | | | | | |
| Feterita bread..... | 1,298.0 | 436.3 | 103.4 | 75.0 | 644.1 | 39.2 |
| Potato..... | 728.0 | 546.0 | 21.8 | ..... | 152.9 | 7.3 |
| Apple sauce..... | 1,016.0 | 914.4 | 3.1 | 3.0 | 93.5 | 2.0 |
| Butter..... | 208.0 | 22.9 | 2.1 | 176.8 | ..... | 6.2 |
| Sugar..... | 128.0 | ..... | ..... | ..... | 128.0 | ..... |
| Total food consumed..... | 3,378.0 | 1,919.6 | 130.4 | 254.8 | 1,018.5 | 54.7 |
| Feces..... | 106.0 | ..... | 53.5 | 12.3 | 29.4 | 10.8 |
| Amount utilized..... | ..... | ..... | 76.9 | 242.5 | 989.1 | 43.9 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 59.0 | 95.2 | 97.1 | 80.3 |
| Estimated digestibility of bread
alone (per cent)..... | | | 56.3 | | 98.5 | |
| Experiment No. 197, subject O. E. S.: | | | | | | |
| Feterita bread..... | 993.0 | 333.8 | 79.1 | 57.4 | 492.7 | 30.0 |
| Potato..... | 702.0 | 526.5 | 21.1 | ..... | 147.4 | 7.0 |
| Apple sauce..... | 941.0 | 846.9 | 2.8 | 2.8 | 86.6 | 1.9 |
| Butter..... | 204.0 | 22.4 | 2.1 | 173.4 | ..... | 6.1 |
| Sugar..... | 193.0 | ..... | ..... | ..... | 193.0 | ..... |
| Total food consumed..... | 3,083.0 | 1,729.6 | 105.1 | 233.6 | 919.7 | 45.0 |
| Feces..... | 110.0 | ..... | 52.9 | 12.3 | 32.6 | 12.2 |
| Amount utilized..... | ..... | ..... | 52.2 | 221.3 | 887.1 | 32.8 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 49.7 | 94.7 | 96.5 | 72.9 |
| Estimated digestibility of bread
alone (per cent)..... | | | 43.1 | | 97.4 | |
| Experiment No. 198, subject R. F. T.: | | | | | | |
| Feterita bread..... | 856.0 | 287.7 | 68.2 | 49.5 | 424.8 | 25.8 |
| Potato..... | 415.0 | 311.2 | 12.5 | ..... | 87.1 | 4.2 |
| Apple sauce..... | 1,018.0 | 916.2 | 3.1 | 3.0 | 93.7 | 2.0 |
| Butter..... | 142.0 | 15.6 | 1.4 | 120.7 | ..... | 4.3 |
| Sugar..... | 178.0 | ..... | ..... | ..... | 178.0 | ..... |
| Total food consumed..... | 2,609.0 | 1,530.7 | 85.2 | 173.2 | 783.6 | 36.3 |
| Feces..... | 74.0 | ..... | 29.7 | 11.4 | 23.5 | 9.4 |
| Amount utilized..... | ..... | ..... | 55.5 | 161.8 | 760.1 | 26.9 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 65.1 | 93.4 | 97.0 | 74.1 |
| Estimated digestibility of bread
alone (per cent)..... | | | 66.3 | | 98.6 | |

Data of digestion experiments with feterita bread in a simple mixed diet—Continued.

| | Weight. | Water. | Protein. | Fat. | Carbohy-
drates. | Ash. |
|--|---------------|---------------|---------------|---------------|---------------------|---------------|
| Experiment No. 203, subject D. G. G.: | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> |
| Feterita bread..... | 1,205.0 | 375.0 | 105.4 | 68.0 | 620.3 | 36.3 |
| Potato..... | 965.0 | 723.7 | 29.0 | | 202.7 | 9.6 |
| Apple sauce..... | 805.0 | 724.5 | 2.4 | 2.4 | 74.1 | 1.6 |
| Butter..... | 306.0 | 33.6 | 3.1 | 260.1 | | 9.2 |
| Sugar..... | 165.0 | | | | 165.0 | |
| Total food consumed..... | 3,446.0 | 1,856.8 | 139.9 | 330.5 | 1,062.1 | 56.7 |
| Feces..... | 157.0 | | 81.6 | 11.3 | 50.6 | 13.5 |
| Amount utilized..... | | | 58.3 | 319.2 | 1,011.5 | 43.2 |
| Digestibility of entire ration (per cent.)..... | | | 41.7 | 96.6 | 95.2 | 76.2 |
| Estimated digestibility of bread alone
(per cent.)..... | | | 30.7 | | 95.2 | |
| Experiment No. 204, subject R. L. S.: | | | | | | |
| Feterita bread..... | 1,298.0 | 403.9 | 113.6 | 73.2 | 668.2 | 39.1 |
| Potato..... | 913.0 | 684.8 | 27.4 | | 191.7 | 9.1 |
| Apple sauce..... | 888.0 | 799.2 | 2.6 | 2.7 | 81.7 | 1.8 |
| Butter..... | 226.0 | 24.8 | 2.3 | 192.1 | | 6.8 |
| Sugar..... | 139.0 | | | | 139.0 | |
| Total food consumed..... | 3,464.0 | 1,912.7 | 145.9 | 268.0 | 1,080.6 | 56.8 |
| Feces..... | 94.0 | | 46.8 | 8.0 | 29.8 | 9.4 |
| Amount utilized..... | | | 99.1 | 260.0 | 1,050.8 | 47.4 |
| Digestibility of entire ration (per cent.)..... | | | 67.9 | 97.0 | 97.2 | 83.5 |
| Estimated digestibility of bread alone
(per cent.)..... | | | 66.5 | | 98.6 | |
| Experiment No. 205, subject O. E. S.: | | | | | | |
| Feterita bread..... | 876.0 | 272.6 | 76.6 | 49.4 | 451.0 | 26.4 |
| Potato..... | 836.0 | 627.0 | 25.1 | | 175.6 | 8.3 |
| Apple sauce..... | 827.0 | 744.3 | 2.5 | 2.5 | 76.1 | 1.6 |
| Butter..... | 182.0 | 20.0 | 1.8 | 154.7 | | 5.5 |
| Sugar..... | 199.0 | | | | 199.0 | |
| Total food consumed..... | 2,920.0 | 1,663.9 | 106.0 | 206.6 | 901.7 | 41.8 |
| Feces..... | 99.0 | | 49.1 | 8.6 | 31.2 | 10.1 |
| Amount utilized..... | | | 56.9 | 198.0 | 870.5 | 31.7 |
| Digestibility of entire ration (per cent.)..... | | | 53.7 | 95.8 | 96.5 | 75.8 |
| Estimated digestibility of bread alone
(per cent.)..... | | | 46.6 | | 97.6 | |
| Experiment No. 206, subject R. F. T.: | | | | | | |
| Feterita bread..... | 850.0 | 264.5 | 74.4 | 47.9 | 437.6 | 25.6 |
| Potato..... | 369.0 | 276.7 | 11.1 | | 77.5 | 3.7 |
| Apple sauce..... | 782.0 | 703.8 | 2.3 | 2.4 | 71.9 | 1.6 |
| Butter..... | 136.0 | 14.9 | 1.4 | 115.6 | | 4.1 |
| Sugar..... | 199.0 | | | | 199.0 | |
| Total food consumed..... | 2,336.0 | 1,259.9 | 89.2 | 165.9 | 786.0 | 35.0 |
| Feces..... | 110.0 | | 48.5 | 12.5 | 36.5 | 12.5 |
| Amount utilized..... | | | 40.7 | 153.4 | 749.5 | 22.5 |
| Digestibility of entire ration (per cent.)..... | | | 45.6 | 92.5 | 95.4 | 64.3 |
| Estimated digestibility of bread alone
(per cent.)..... | | | 42.1 | | 95.1 | |
| Average food consumed per subject per day..... | 1,034.1 | 577.8 | 39.5 | 81.0 | 319.6 | 16.2 |

Summary of digestion experiments with feterita bread in a simple mixed diet.

| Experi-
ment No. | Subject. | Protein. | Carbohy-
drates. | Experi-
ment No. | Subject. | Protein. | Carbohy-
drates. |
|---------------------|--------------|------------------|---------------------|---------------------|--------------|------------------|---------------------|
| 195..... | D. G. G..... | <i>Per cent.</i> | <i>Per cent.</i> | 204..... | R. L. S..... | <i>Per cent.</i> | <i>Per cent.</i> |
| 196..... | R. L. S..... | 52.9 | 98.0 | 205..... | O. E. S..... | 66.5 | 98.6 |
| 197..... | O. E. S..... | 56.3 | 98.5 | 206..... | R. F. T..... | 46.6 | 97.6 |
| 198..... | R. F. T..... | 43.1 | 97.4 | | | 42.1 | 95.1 |
| 203..... | D. G. G..... | 66.3 | 98.6 | | Average..... | 50.6 | 97.4 |
| | | 30.7 | 95.2 | | | | |

In the test periods in which feterita bread was eaten, an average of 31 grams of protein and 185 grams of carbohydrate was supplied daily by the bread, the protein being 50.6 per cent and the carbohydrate 97.4 per cent digested. As with the other sorghums, although the meal was coarse and apparently increased the peristaltic action of the intestine, no physiological disturbances were experienced.

DIGESTION EXPERIMENTS WITH MILO BREAD.

Milo bread flavored with ginger was used in this series of tests, being supplemented by a simple mixed diet like that provided for the other experiments of this series. Four subjects assisted in the eight digestion experiments, the results of which are recorded in the following tables:

Data of digestion experiments with milo bread in a simple mixed diet.

| | Weight. | Water. | Protein. | Fat. | Carbohy-
drates. | Ash. |
|---|---------------|---------------|---------------|---------------|---------------------|---------------|
| | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> |
| Experiment No. 171, subject D. G. G.: | | | | | | |
| Milo bread..... | 1,247.0 | 389.4 | 94.3 | 79.2 | 647.9 | 26.2 |
| Potato..... | 743.0 | 557.3 | 22.3 | | 156.0 | 7.4 |
| Apple sauce..... | 871.0 | 783.9 | 2.6 | 2.6 | 80.1 | 1.8 |
| Butter..... | 200.0 | 22.0 | 2.0 | 170.0 | | 6.0 |
| Sugar..... | 252.0 | | | | 252.0 | |
| Total food consumed..... | 3,313.0 | 1,752.6 | 121.2 | 251.8 | 1,136.0 | 51.4 |
| Feces..... | 148.0 | | 72.4 | 12.2 | 50.2 | 13.2 |
| Amount utilized..... | | | 48.8 | 239.6 | 1,085.8 | 38.2 |
| Digestibility of entire ration (per cent)..... | | | 40.3 | 95.2 | 95.6 | 74.3 |
| Estimated digestibility of bread alone
(per cent)..... | | | 31.5 | | 95.5 | |
| Experiment No. 172, subject R. L. S.: | | | | | | |
| Milo bread..... | 1,336.0 | 417.2 | 101.0 | 84.8 | 694.2 | 38.8 |
| Potato..... | 776.9 | 582.0 | 23.3 | | 163.0 | 7.7 |
| Apple sauce..... | 1,075.0 | 967.5 | 3.2 | 3.2 | 98.9 | 2.2 |
| Butter..... | 213.0 | 23.4 | 2.1 | 181.1 | | 6.4 |
| Sugar..... | 100.0 | | | | 100.0 | |
| Total food consumed..... | 3,500.0 | 1,990.1 | 129.6 | 269.1 | 1,056.1 | 55.1 |
| Feces..... | 133.0 | | 63.9 | 21.5 | 34.4 | 13.2 |
| Amount utilized..... | | | 65.7 | 247.6 | 1,021.7 | 41.9 |
| Digestibility of entire ration (per cent)..... | | | 50.7 | 92.0 | 96.7 | 76.0 |
| Estimated digestibility of bread alone
(per cent)..... | | | 45.5 | | 97.9 | |
| Experiment No. 173, subject O. E. S.: | | | | | | |
| Milo bread..... | 1,256.0 | 392.2 | 95.0 | 79.8 | 652.6 | 36.4 |
| Potato..... | 651.0 | 488.3 | 19.5 | | 136.7 | 6.5 |
| Apple sauce..... | 986.0 | 887.4 | 3.0 | 2.9 | 90.7 | 2.0 |
| Butter..... | 226.0 | 24.8 | 2.3 | 192.1 | | 6.8 |
| Sugar..... | 217.0 | | | | 217.0 | |
| Total food consumed..... | 3,336.0 | 1,792.7 | 119.8 | 274.8 | 1,097.0 | 51.7 |
| Feces..... | 116.0 | | 55.7 | 10.7 | 37.9 | 11.7 |
| Amount utilized..... | | | 64.1 | 264.1 | 1,059.1 | 40.0 |
| Digestibility of entire ration (per cent)..... | | | 53.5 | 96.1 | 96.5 | 77.4 |
| Estimated digestibility of bread alone
(per cent)..... | | | 49.7 | | 97.3 | |
| Experiment No. 174, subject R. F. T.: | | | | | | |
| Milo bread..... | 1,007.0 | 314.5 | 76.1 | 63.9 | 523.2 | 29.3 |
| Potato..... | 443.0 | 332.3 | 13.3 | | 93.0 | 4.4 |
| Apple sauce..... | 1,105.0 | 994.5 | 3.3 | 3.3 | 101.7 | 2.2 |
| Butter..... | 150.0 | 16.5 | 1.5 | 127.5 | | 4.5 |
| Sugar..... | 253.0 | | | | 253.0 | |
| Total food consumed..... | 2,958.0 | 1,657.8 | 94.2 | 194.7 | 970.9 | 40.4 |
| Feces..... | 119.0 | | 51.2 | 13.7 | 42.4 | 11.7 |
| Amount utilized..... | | | 43.0 | 181.0 | 928.5 | 28.7 |
| Digestibility of entire ration (per cent)..... | | | 45.6 | 93.0 | 95.6 | 71.0 |
| Estimated digestibility of bread alone
(per cent)..... | | | 42.3 | | 95.8 | |

Data of digestion experiments with milo bread in a simple mixed diet—Continued.

| | Weight. | Water. | Protein. | Fat. | Carbohy-
drates. | Ash. |
|---|---------------|---------------|---------------|---------------|---------------------|---------------|
| | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> |
| Experiment No. 218, subject D. G. G.: | | | | | | |
| Milo bread..... | 1,745.0 | 573.2 | 130.9 | 89.3 | 902.3 | 49.3 |
| Potato..... | 819.0 | 606.0 | 24.6 | | 180.2 | 8.2 |
| Apple sauce..... | 1,107.0 | 996.3 | 3.3 | 3.3 | 101.9 | 2.2 |
| Butter..... | 340.0 | 37.4 | 3.4 | 289.0 | | 10.2 |
| Sugar..... | 185.0 | | | | 185.0 | |
| Total food consumed..... | 4,196.0 | 2,212.9 | 162.2 | 381.6 | 1,369.4 | 69.9 |
| Feces..... | 159.0 | | 81.5 | 11.5 | 51.4 | 14.6 |
| Amount utilized..... | | | 80.7 | 370.1 | 1,318.0 | 55.3 |
| Digestibility of entire ration (per cent)..... | | | 49.8 | 97.0 | 96.2 | 79.1 |
| Estimated digestibility of bread alone
(per cent)..... | | | 44.8 | | 96.8 | |
| Experiment No. 219, subject R. L. S.: | | | | | | |
| Milo bread..... | 1,727.0 | 567.3 | 129.5 | 88.4 | 893.0 | 48.8 |
| Potato..... | 788.0 | 583.1 | 23.6 | | 173.4 | 7.9 |
| Apple sauce..... | 1,075.0 | 967.5 | 3.2 | 3.2 | 98.9 | 2.2 |
| Butter..... | 225.0 | 24.8 | 2.2 | 191.2 | | 6.8 |
| Sugar..... | 110.0 | | | | 110.0 | |
| Total food consumed..... | 3,925.0 | 2,142.7 | 158.5 | 282.8 | 1,275.3 | 65.7 |
| Feces..... | 142.0 | | 72.9 | 15.4 | 38.8 | 14.9 |
| Amount utilized..... | | | 85.6 | 267.4 | 1,236.5 | 50.8 |
| Digestibility of entire ration (per cent)..... | | | 54.0 | 94.6 | 97.0 | 77.3 |
| Estimated digestibility of bread alone
(per cent)..... | | | 50.6 | | 98.0 | |
| Experiment No. 220, subject O. E. S.: | | | | | | |
| Milo bread..... | 1,855.0 | 609.4 | 139.1 | 95.0 | 959.2 | 52.3 |
| Potato..... | 747.0 | 552.8 | 22.4 | | 164.3 | 7.5 |
| Apple sauce..... | 1,228.0 | 1,105.2 | 3.7 | 3.7 | 113.0 | 2.4 |
| Butter..... | 300.0 | 33.0 | 3.0 | 255.0 | | 9.0 |
| Sugar..... | 322.0 | | | | 322.0 | |
| Total food consumed..... | 4,452.0 | 2,300.4 | 168.2 | 353.7 | 1,558.5 | 71.2 |
| Feces..... | 216.0 | | 104.6 | 18.8 | 71.8 | 20.8 |
| Amount utilized..... | | | 63.6 | 334.9 | 1,486.7 | 50.4 |
| Digestibility of entire ration (per cent)..... | | | 37.8 | 94.7 | 95.4 | 70.8 |
| Estimated digestibility of bread alone
(per cent)..... | | | 31.6 | | 95.2 | |
| Experiment No. 221, subject R. F. T.: | | | | | | |
| Milo bread..... | 1,435.0 | 471.4 | 107.6 | 73.5 | 742.0 | 40.5 |
| Potato..... | 595.0 | 440.3 | 17.8 | | 130.9 | 6.0 |
| Apple sauce..... | 1,128.0 | 1,015.2 | 3.4 | 3.4 | 103.8 | 2.2 |
| Butter..... | 240.0 | 26.4 | 2.4 | 204.0 | | 7.2 |
| Sugar..... | 293.0 | | | | 293.0 | |
| Total food consumed..... | 3,691.0 | 1,953.3 | 131.2 | 280.9 | 1,269.7 | 55.9 |
| Feces..... | 205.0 | | 89.6 | 24.1 | 68.4 | 22.9 |
| Amount utilized..... | | | 41.6 | 256.8 | 1,201.3 | 33.0 |
| Digestibility of entire ration (per cent)..... | | | 31.7 | 91.4 | 94.6 | 59.0 |
| Estimated digestibility of bread alone
(per cent)..... | | | 24.3 | | 93.9 | |
| Average food consumed per subject per
day..... | 1,223.8 | 658.5 | 45.2 | 95.4 | 405.5 | 19.2 |

Summary of digestion experiments with milo bread in a simple mixed diet.

| Experiment
No. | Subject. | Protein. | Carbohy-
drates. | Experiment
No. | Subject. | Protein. | Carbohy-
drates. |
|-------------------|--------------|------------------|---------------------|-------------------|--------------|------------------|---------------------|
| | | <i>Per cent.</i> | <i>Per cent.</i> | | | <i>Per cent.</i> | <i>Per cent.</i> |
| 171..... | D. G. G..... | 31.5 | 95.5 | 219..... | R. L. S..... | 50.6 | 98.0 |
| 172..... | R. L. S..... | 45.5 | 97.9 | 220..... | O. E. S..... | 31.6 | 95.2 |
| 173..... | O. E. S..... | 49.7 | 97.3 | 221..... | F. F. T..... | 24.3 | 93.9 |
| 174..... | R. F. T..... | 42.3 | 95.8 | | | | |
| 218..... | D. G. G..... | 44.8 | 96.8 | | Average..... | 40.0 | 96.3 |

In the diet containing large quantities of milo bread, the bread supplied an average of 36 grams of protein and 251 grams of carbohydrate, which were estimated to be 40.0 per cent and 96.3 per cent digested, respectively. In these experiments, as in the tests with the other sorghums, owing to the low protein content of the grains, it would have been very difficult for the subjects to eat a sufficient bulk of the diet to obtain the amount of protein specified in the common dietary standards, namely, 100 grams per man of average weight daily.

DIGESTION EXPERIMENTS WITH KAOLIANG BREAD.

Kaoliang bread, or, perhaps better, gingerbread (also flavored with ginger), was very similar in taste and appearance to the other sorghum breads. Indeed, all the sorghum gingerbreads so clearly resembled one another that the subjects apparently believed that they were all prepared from the same meal. The essential data of the digestion experiments with four subjects are reported as follows:

Data of digestion experiments with kaoliang bread in a simple mixed diet.

| | Weight. | Water. | Protein. | Fat. | Carbohydrates. | Ash. |
|--|---------------|---------------|---------------|---------------|----------------|---------------|
| Experiment No. 378, subject D. G. G.: | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> |
| Kaoliang bread..... | 1,419.0 | 203.6 | 134.8 | 124.9 | 920.4 | 35.3 |
| Potato..... | 632.0 | 474.0 | 19.0 | | 132.7 | 6.3 |
| Apple sauce..... | 1,045.0 | 914.4 | 3.3 | 4.3 | 120.5 | 2.5 |
| Butter..... | 374.0 | 41.2 | 3.7 | 317.9 | | 11.2 |
| Sugar..... | 94.0 | | | | 94.0 | |
| Total food consumed..... | 3,564.0 | 1,633.2 | 160.8 | 447.1 | 1,267.6 | 55.3 |
| Feces..... | 194.0 | | 102.5 | 22.5 | 53.6 | 15.4 |
| Amount utilized..... | | | 58.3 | 424.6 | 1,214.0 | 39.9 |
| Digestibility of entire ration (per cent)..... | | | 36.3 | 95.0 | 95.8 | 72.2 |
| Estimated digestibility of bread alone (per cent)..... | | | 26.8 | | 96.4 | |
| Experiment No. 379, subject A. J. H.: | | | | | | |
| Kaoliang bread..... | 1,323.0 | 189.9 | 125.7 | 116.4 | 858.1 | 32.9 |
| Potato..... | 599.0 | 449.2 | 18.0 | | 125.8 | 6.0 |
| Apple sauce..... | 947.0 | 828.6 | 3.0 | 3.9 | 109.2 | 2.3 |
| Butter..... | 337.0 | 37.1 | 3.4 | 286.4 | | 10.1 |
| Sugar..... | 44.0 | | | | 44.0 | |
| Total food consumed..... | 3,250.0 | 1,504.8 | 150.1 | 406.7 | 1,137.1 | 51.3 |
| Feces..... | 213.0 | | 109.0 | 34.6 | 48.3 | 21.1 |
| Amount utilized..... | | | 41.1 | 372.1 | 1,088.8 | 30.2 |
| Digestibility of entire ration (per cent)..... | | | 27.4 | 91.5 | 95.8 | 58.9 |
| Estimated digestibility of bread alone (per cent)..... | | | 16.1 | | 96.5 | |
| Experiment No. 380, subject R. L. S.: | | | | | | |
| Kaoliang bread..... | 1,431.0 | 205.4 | 135.9 | 125.9 | 928.2 | 35.6 |
| Potato..... | 587.0 | 440.2 | 17.6 | | 123.3 | 5.9 |
| Apple sauce..... | 1,073.0 | 938.9 | 3.4 | 4.4 | 123.7 | 2.6 |
| Butter..... | 270.0 | 29.7 | 2.7 | 229.5 | | 8.1 |
| Sugar..... | 121.0 | | | | 121.0 | |
| Total food consumed..... | 3,482.0 | 1,614.2 | 159.6 | 359.8 | 1,296.2 | 52.2 |
| Feces..... | 235.0 | | 119.1 | 30.3 | 64.0 | 21.6 |
| Amount utilized..... | | | 40.5 | 329.5 | 1,232.2 | 30.6 |
| Digestibility of entire ration (per cent)..... | | | 25.4 | 91.6 | 95.0 | 58.6 |
| Estimated digestibility of bread alone (per cent)..... | | | 15.0 | | 95.4 | |

Data of digestion experiments with kaoliang bread in a simple mixed diet—Continued.

| | Weight. | Water. | Protein. | Fat. | Carbohy-
drates. | Ash. |
|---|---------------|---------------|---------------|---------------|---------------------|---------------|
| Experiment No. 381, subject O. E. S.: | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> |
| Kaoliang bread | 1,228.0 | 176.2 | 116.6 | 108.1 | 796.5 | 30.6 |
| Potato | 563.0 | 422.3 | 16.9 | ..... | 118.2 | 5.6 |
| Apple sauce | 1,002.0 | 876.8 | 3.2 | 4.1 | 115.5 | 2.4 |
| Butter | 257.0 | 28.3 | 2.6 | 218.4 | ..... | 7.7 |
| Sugar | 183.0 | ..... | ..... | ..... | 183.0 | ..... |
| Total food consumed | 3,233.0 | 1,503.6 | 139.3 | 330.6 | 1,213.2 | 46.3 |
| Feces | 156.0 | ..... | 80.5 | 19.2 | 41.5 | 14.8 |
| Amount utilized ..... | ..... | ..... | 58.8 | 311.4 | 1,171.7 | 31.5 |
| Digestibility of entire ration (per cent) ..... | ..... | ..... | 42.2 | 94.2 | 96.6 | 68.0 |
| Estimated digestibility of bread alone (per cent) ..... | ..... | ..... | 34.0 | ..... | 97.5 | ..... |
| Experiment No. 393, subject D. G. G.: | | | | | | |
| Kaoliang bread | 1,828.0 | 496.7 | 139.3 | 147.5 | 1,008.0 | 36.5 |
| Potato | 699.0 | 527.7 | 17.5 | .7 | 146.1 | 7.0 |
| Apple sauce | 912.0 | 821.9 | 2.4 | 2.9 | 83.1 | 1.7 |
| Butter | 385.0 | 42.3 | 3.8 | 327.3 | ..... | 11.6 |
| Sugar | 167.0 | ..... | ..... | ..... | 167.0 | ..... |
| Total food consumed | 3,991.0 | 1,888.6 | 163.0 | 478.4 | 1,404.2 | 56.8 |
| Feces | 241.0 | ..... | 126.1 | 23.2 | 71.5 | 20.2 |
| Amount utilized ..... | ..... | ..... | 36.9 | 455.2 | 1,332.7 | 36.6 |
| Digestibility of entire ration (per cent) ..... | ..... | ..... | 22.6 | 95.2 | 94.9 | 64.4 |
| Estimated digestibility of bread alone (per cent) ..... | ..... | ..... | 12.0 | ..... | 94.8 | ..... |
| Experiment No. 394, subject A. J. H.: | | | | | | |
| Kaoliang bread | 1,458.0 | 396.1 | 111.1 | 117.7 | 803.9 | 29.2 |
| Potato | 765.0 | 577.6 | 19.1 | .8 | 159.9 | 7.6 |
| Apple sauce | 841.0 | 757.9 | 2.2 | 2.7 | 76.6 | 1.6 |
| Butter | 244.0 | 26.9 | 2.4 | 207.4 | ..... | 7.3 |
| Sugar | 93.0 | ..... | ..... | ..... | 93.0 | ..... |
| Total food consumed | 3,401.0 | 1,758.5 | 134.8 | 328.6 | 1,133.4 | 45.7 |
| Feces | 189.0 | ..... | 97.8 | 27.6 | 44.4 | 19.2 |
| Amount utilized ..... | ..... | ..... | 37.0 | 301.0 | 1,089.0 | 26.5 |
| Digestibility of entire ration (per cent) ..... | ..... | ..... | 27.4 | 91.6 | 96.1 | 58.0 |
| Estimated digestibility of bread alone (per cent) ..... | ..... | ..... | 15.2 | ..... | 96.7 | ..... |
| Experiment No. 395, subject R. L. S.: | | | | | | |
| Kaoliang bread | 1,483.0 | 402.9 | 113.0 | 119.7 | 817.7 | 29.7 |
| Potato | 588.0 | 443.9 | 14.7 | .6 | 122.9 | 5.9 |
| Apple sauce | 966.0 | 870.6 | 2.5 | 3.1 | 88.0 | 1.8 |
| Butter | 297.0 | 32.7 | 3.0 | 252.4 | ..... | 8.9 |
| Sugar | 99.0 | ..... | ..... | ..... | 99.0 | ..... |
| Total food consumed | 3,433.0 | 1,750.1 | 133.2 | 375.8 | 1,127.6 | 46.3 |
| Feces | 186.0 | ..... | 97.9 | 21.4 | 47.8 | 18.9 |
| Amount utilized ..... | ..... | ..... | 35.3 | 354.4 | 1,079.8 | 27.4 |
| Digestibility of entire ration (per cent) ..... | ..... | ..... | 26.5 | 94.3 | 95.8 | 59.2 |
| Estimated digestibility of bread alone (per cent) ..... | ..... | ..... | 16.0 | ..... | 96.2 | ..... |
| Experiment No. 396, subject O. E. S.: | | | | | | |
| Kaoliang bread | 1,427.0 | 387.7 | 108.7 | 115.2 | 786.9 | 28.5 |
| Potato | 712.0 | 537.6 | 17.8 | .7 | 148.8 | 7.1 |
| Apple sauce | 946.0 | 852.5 | 2.5 | 3.0 | 86.2 | 1.8 |
| Butter | 258.0 | 28.4 | 2.6 | 219.3 | ..... | 7.7 |
| Sugar | 324.0 | ..... | ..... | ..... | 324.0 | ..... |
| Total food consumed | 3,667.0 | 1,806.2 | 131.6 | 338.2 | 1,345.9 | 45.1 |
| Feces | 171.0 | ..... | 86.8 | 17.1 | 50.1 | 17.0 |
| Amount utilized ..... | ..... | ..... | 44.8 | 321.1 | 1,295.8 | 28.1 |
| Digestibility of entire ration (per cent) ..... | ..... | ..... | 34.0 | 94.9 | 96.3 | 62.3 |
| Estimated digestibility of bread alone (per cent) ..... | ..... | ..... | 23.4 | ..... | 96.5 | ..... |
| Average food consumed per subject per day | 1,167.5 | 560.8 | 48.8 | 127.7 | 413.6 | 16.6 |

Summary of digestion experiments with kaoliang bread in a simple mixed diet.

| Experi-
ment No. | Subject. | Protein. | Carbohy-
drates. | Experi-
ment No. | Subject. | Protein. | Carbohy-
drates. |
|---------------------|--------------|------------------|---------------------|---------------------|--------------|------------------|---------------------|
| | | <i>Per cent.</i> | <i>Per cent.</i> | | | <i>Per cent.</i> | <i>Per cent.</i> |
| 378..... | D. G. G..... | 26.8 | 96.4 | 394..... | A. J. H..... | 15.2 | 96.7 |
| 379..... | A. J. H..... | 16.1 | 96.5 | 395..... | R. L. S..... | 16.0 | 96.2 |
| 380..... | R. L. S..... | 15.0 | 95.4 | 396..... | O. E. S..... | 23.4 | 96.5 |
| 381..... | O. E. S..... | 34.0 | 97.5 | | | | |
| 393..... | D. G. G..... | 12.0 | 94.8 | | Average..... | 19.8 | 96.3 |

In the experiments with kaoliang, notwithstanding the fact that the subjects ate nearly a pound of this bread daily, it supplied on an average only 41 grams of protein and 288 grams of carbohydrate per man per day. As the data recorded above show, the bread protein was found to be only 19.8 per cent available to the body, while the digestibility of carbohydrate proved to be 96.3 per cent.

SUMMARY OF DATA ON THE DIGESTIBILITY OF THE GRAIN-SORGHUM BREADS.

Considering the experiments with the sorghum gingerbreads as a whole, the digestibility of the protein of bread alone averaged less than 50 per cent, while that of the carbohydrate constituent of the bread was found to be uniformly high. That the digestibility of the carbohydrate from the sorghum meals alone is practically identical with that of the breads alone is evident from the fact that the only accessory carbohydrate present in the breads was a relatively small quantity of molasses—a carbohydrate whose digestibility is 98 per cent. Moreover the averages for the digestibility of carbohydrate from kafir, feterita, milo, and kaoliang breads are practically identical with the value usually given for the average simple mixed diet—namely, 97 per cent.¹ The close agreement of these values is of particular interest, for it indicates that the low values obtained for the digestibility of protein are not due to errors in the collections of the feces.

The subjects reported as a rule that they seemed to be in normal condition throughout the experimental periods. The diets containing the grain sorghums seemed to assist materially the peristaltic action of the intestine—an effect which was probably due to the large bulk of unassimilated material which the sorghum meals supply. In one or two instances the subjects reported sensations of hunger and nervous headache, but this was probably due to the fact that too little nutritive material was eaten to supply the body needs.

It is thought that sufficient experimental data have been accumulated in this series of experiments to permit of an accurate comparison of the digestibility of the sorghums one with another. In order to ascertain their digestibility as compared with other cereals, a series of check experiments has been made with corn and wheat meal prepared in the same way and eaten with the same basal ration.

¹ Connecticut Storrs Sta. Rpt. 1901, p. 245.

CHECK EXPERIMENTS WITH BREADS MADE FROM CORN AND WHEAT MEALS.

The corn and wheat breads used in the following tests were prepared in the same way as the sorghum gingerbreads (p. 5) and were eaten with the same basal ration of apple sauce, potatoes, and butter. To make certain that the results of these tests should be directly comparable with those of the preceding experiments, the details of the daily routine and all other conditions essential to accurate work were made to correspond nearly exactly. It is to be especially noted that the corn and wheat meals used to make the bread were ground in the same mill as were the sorghum grains and to the same degree of fineness. Such a precaution was necessary in order to remove approximately the same percentage of bran from all of the grains.

Seven digestion experiments, each of the customary three days' duration, were conducted with the cooperation of four subjects. The results of these tests are reported in the following tables:

Data of digestion experiments with corn bread in a simple mixed diet.

| | Weight. | Water. | Protein. | Fat. | Carbohydrates. | Ash. |
|--|---------------|---------------|---------------|---------------|----------------|---------------|
| Experiment No. 231, subject, D. G. G.: | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> |
| Corn bread..... | 1,877.0 | 773.9 | 86.7 | 89.9 | 889.3 | 37.2 |
| Potato..... | 581.0 | 430.0 | 17.4 | ..... | 127.8 | 5.8 |
| Apple sauce..... | 950.0 | 855.0 | 2.9 | 2.8 | 87.4 | 1.9 |
| Butter..... | 355.0 | 39.0 | 3.5 | 301.8 | ..... | 10.7 |
| Sugar..... | 175.0 | ..... | ..... | ..... | 175.0 | ..... |
| Total food consumed..... | 3,938.0 | 2,097.9 | 110.5 | 394.5 | 1,279.5 | 55.6 |
| Feces..... | 139.0 | ..... | 45.5 | 19.2 | 62.6 | 11.7 |
| Amount utilized..... | ..... | ..... | 65.0 | 375.3 | 1,216.9 | 43.9 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 58.8 | 95.1 | 95.1 | 79.0 |
| Estimated digestibility of bread alone (per cent)..... | ..... | ..... | 56.3 | ..... | 95.1 | ..... |
| Experiment No. 232, subject, R. L. S.: | | | | | | |
| Corn bread..... | 1,957.0 | 806.9 | 90.5 | 93.7 | 927.2 | 38.7 |
| Potato..... | 526.0 | 389.2 | 15.8 | ..... | 115.7 | 5.3 |
| Apple sauce..... | 834.0 | 750.6 | 2.5 | 2.5 | 76.7 | 1.7 |
| Butter..... | 228.0 | 25.1 | 2.3 | 193.8 | ..... | 6.8 |
| Sugar..... | 82.0 | ..... | ..... | ..... | 82.0 | ..... |
| Total food consumed..... | 3,627.0 | 1,971.8 | 111.1 | 290.0 | 1,201.6 | 52.5 |
| Feces..... | 101.0 | ..... | 33.6 | 16.5 | 41.5 | 9.4 |
| Amount utilized..... | ..... | ..... | 77.5 | 273.5 | 1,160.1 | 43.1 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 69.8 | 94.3 | 96.5 | 82.1 |
| Estimated digestibility of bread alone (per cent)..... | ..... | ..... | 70.1 | ..... | 97.2 | ..... |
| Experiment No. 233, subject O. E. S.: | | | | | | |
| Corn bread..... | 2,129.0 | 877.8 | 98.4 | 102.0 | 1,008.7 | 42.1 |
| Potato..... | 670.0 | 495.8 | 20.1 | ..... | 147.4 | 6.7 |
| Apple sauce..... | 849.0 | 764.1 | 2.5 | 2.6 | 78.1 | 1.7 |
| Butter..... | 293.0 | 32.2 | 2.9 | 249.1 | ..... | 8.8 |
| Sugar..... | 344.0 | ..... | ..... | ..... | 344.0 | ..... |
| Total food consumed..... | 4,285.0 | 2,169.9 | 123.9 | 353.7 | 1,578.2 | 59.3 |
| Feces..... | 148.0 | ..... | 53.5 | 21.3 | 60.8 | 12.4 |
| Amount utilized..... | ..... | ..... | 70.4 | 332.4 | 1,517.4 | 46.9 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 56.8 | 94.0 | 96.1 | 79.1 |
| Estimated digestibility of bread alone (per cent)..... | ..... | ..... | 53.2 | ..... | 96.2 | ..... |
| Average food consumed per subject per day..... | 1,316.7 | 693.3 | 38.4 | 115.4 | 451.0 | 18.6 |

Summary of digestion experiments with corn bread in a simple mixed diet.

| Experiment No. | Subject. | Protein. | Carbohy-
drates. |
|----------------|--------------|------------------|---------------------|
| | | <i>Per cent.</i> | <i>Per cent.</i> |
| 231..... | D. G. G..... | 56.3 | 95.1 |
| 232..... | R. L. S..... | 70.1 | 97.2 |
| 233..... | O. E. S..... | 53.2 | 96.2 |
| | Average..... | 59.9 | 96.2 |

Data of digestion experiments with wheat bread in a simple mixed diet.

| | Weight. | Water. | Protein. | Fat. | Carbohy-
drates. | Ash. |
|--|---------------|---------------|---------------|---------------|---------------------|---------------|
| | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> |
| Experiment No. 226, subject D. G. G.: | | | | | | |
| Wheat bread..... | 2,035.0 | 823.4 | 155.1 | 110.1 | 890.2 | 56.2 |
| Potato..... | 478.0 | 353.7 | 14.3 | ..... | 105.2 | 4.8 |
| Apple sauce..... | 904.0 | 813.6 | 2.7 | 2.7 | 83.2 | 1.8 |
| Butter..... | 307.0 | 33.8 | 3.1 | 260.9 | ..... | 9.2 |
| Sugar..... | 193.0 | ..... | ..... | ..... | 193.0 | ..... |
| Total food consumed..... | 3,917.0 | 2,024.5 | 175.2 | 373.7 | 1,271.6 | 72.0 |
| Feces..... | 153.0 | ..... | 48.4 | 13.7 | 74.7 | 16.2 |
| Amount utilized..... | ..... | ..... | 126.8 | 360.0 | 1,196.9 | 55.8 |
| Digestibility of entire ration (per cent.)..... | ..... | ..... | 72.4 | 96.3 | 94.1 | 77.5 |
| Estimated digestibility of bread alone
(per cent.)..... | | | 73.0 | | 93.6 | |
| Experiment No. 227, subject R. L. S.: | | | | | | |
| Wheat bread..... | 1,807.0 | 731.0 | 137.8 | 97.8 | 790.5 | 49.9 |
| Potato..... | 509.0 | 376.6 | 15.3 | ..... | 112.0 | 5.1 |
| Apple sauce..... | 909.0 | 818.1 | 2.7 | 2.7 | 83.7 | 1.8 |
| Butter..... | 192.0 | 21.1 | 1.9 | 163.2 | ..... | 5.8 |
| Sugar..... | 121.0 | ..... | ..... | ..... | 121.0 | ..... |
| Total food consumed..... | 3,538.0 | 1,946.8 | 157.7 | 263.7 | 1,107.2 | 62.6 |
| Feces..... | 71.0 | ..... | 22.1 | 9.1 | 31.3 | 8.5 |
| Amount utilized..... | ..... | ..... | 135.6 | 254.6 | 1,075.9 | 54.1 |
| Digestibility of entire ration (per cent.)..... | ..... | ..... | 86.0 | 96.5 | 97.2 | 86.4 |
| Estimated digestibility of bread alone
(per cent.)..... | | | 88.8 | | 98.1 | |
| Experiment No. 228, subject O. E. S.: | | | | | | |
| Wheat bread..... | 2,137.0 | 864.6 | 163.0 | 115.6 | 934.8 | 59.0 |
| Potato..... | 591.0 | 437.4 | 17.7 | ..... | 130.0 | 5.9 |
| Apple sauce..... | 880.0 | 792.0 | 2.6 | 2.6 | 81.0 | 1.8 |
| Butter..... | 262.0 | 28.8 | 2.6 | 222.7 | ..... | 7.9 |
| Sugar..... | 313.0 | ..... | ..... | ..... | 313.0 | ..... |
| Total food consumed..... | 4,183.0 | 2,122.8 | 185.9 | 340.9 | 1,458.8 | 74.6 |
| Feces..... | 200.0 | ..... | 61.8 | 30.5 | 84.6 | 23.1 |
| Amount utilized..... | ..... | ..... | 124.1 | 310.4 | 1,374.2 | 51.5 |
| Digestibility of entire ration (per cent.)..... | ..... | ..... | 66.8 | 91.1 | 94.2 | 69.0 |
| Estimated digestibility of bread alone
(per cent.)..... | | | 66.4 | | 93.2 | |
| Experiment No. 229, subject R. F. T.: | | | | | | |
| Wheat bread..... | 1,401.0 | 566.8 | 106.8 | 75.8 | 612.9 | 38.7 |
| Potato..... | 346.0 | 256.0 | 10.4 | ..... | 76.1 | 3.5 |
| Apple sauce..... | 882.0 | 793.8 | 2.7 | 2.6 | 81.1 | 1.8 |
| Butter..... | 154.0 | 17.0 | 1.5 | 130.9 | ..... | 4.6 |
| Sugar..... | 220.0 | ..... | ..... | ..... | 220.0 | ..... |
| Total food consumed..... | 3,003.0 | 1,633.6 | 121.4 | 209.3 | 990.1 | 48.6 |
| Feces..... | 92.0 | ..... | 26.0 | 15.6 | 38.2 | 12.2 |
| Amount utilized..... | ..... | ..... | 95.4 | 193.7 | 951.9 | 36.4 |
| Digestibility of entire ration (per cent.)..... | ..... | ..... | 78.6 | 92.5 | 96.1 | 74.9 |
| Estimated digestibility of bread alone
(per cent.)..... | | | 81.0 | | 96.4 | |
| Average food consumed per subject
per day..... | 1,220.1 | 644.0 | 53.3 | 99.0 | 402.3 | 21.5 |

Summary of digestion experiments with wheat bread in a simple mixed diet.

| Experi-
ment No. | Subject. | Protein. | Carbo-
hydrates. | Experi-
ment No. | Subject. | Protein. | Carbo-
hydrates. |
|---------------------|--------------|------------------|---------------------|---------------------|--------------|------------------|---------------------|
| | | <i>Per cent.</i> | <i>Per cent.</i> | | | <i>Per cent.</i> | <i>Per cent.</i> |
| 226..... | D. G. G..... | 73.0 | 93.6 | 229..... | R. F. T..... | 81.0 | 96.4 |
| 227..... | R. L. S..... | 88.8 | 98.1 | | | | |
| 228..... | O. E. S..... | 66.4 | 93.2 | | Average..... | 77.3 | 95.3 |

The digestibility of fat and carbohydrate in both the corn and the wheat bread diets was very satisfactory, 94.5 per cent of fat and 95.9 per cent of carbohydrate in the ration containing corn, and 94.1 per cent of fat and 95.4 per cent of carbohydrate in the wheat diet representing the percentages of available nutrients. The estimated value for the digestibility of the carbohydrate of corn bread alone is 96.2 per cent and of the carbohydrate of wheat bread 95.3 per cent.

An average of 38.4 grams of protein per man per day was 61.8 per cent digested in the experiments with corn bread and, although the average daily consumption of protein in the experiments with wheat was only 53.3 grams, this was 76.0 per cent available to the body. The estimated digestibility of the protein supplied by the corn bread alone is 59.9 per cent, and of the protein supplied by wheat bread 77.3 per cent. These values undoubtedly vary with the quantity of bran present in the flour and with other experimental conditions, such as the nature of the diet and the quantity of protein eaten. This opinion is in accordance with the conclusions of other investigators. Results of experiments by Woods and Merrill,¹ conducted in cooperation with the earlier work of the Office of Home Economics, indicate that all kinds of wheat bread are well digested and deserving of the important place given to them in the diet. These investigators found that the digestibility of the protein of wheat bread varied from 93.8 per cent for standard patent to 80 per cent for entire wheat flour. Snyder² also studied the comparative digestibility of protein in different grades of wheat flour, finding that although the entire wheat and graham flours contained more protein than the patent flours, the percentages of protein actually available to the body was greater in the patent flour. In experiments with Indian corn meal prepared for eating in several different ways, Merrill³ found a digestibility of protein varying from 73 to 86 per cent.

The digestibility of corn protein herein determined, 59.9 per cent, is somewhat lower than that usually reported, but it seems reasonable to conclude, in comparison with the preceding experiments with the grain sorghums in identically the same basal ration, that corn protein is more thoroughly digested than are the protein constituents of dwarf

¹ U. S. Dept. Agr., Office Expt. Sta. Bul. 143 (1904), p. 33. ² Maine Sta. Bul. 131 (1906).

³ Idem, 126 (1903), p. 46; 156 (1905).

kafir, feterita, dwarf milo, and kaoliang. As indicated by its digestibility, 77.3 per cent, wheat protein is even more completely available to the body. Since the sorghums contain less protein than is found in either corn or wheat, and as these tests indicate that the protein, gram for gram, is less thoroughly digested than that of corn and wheat, it may be concluded that both corn and wheat contain more available protein than do the sorghum grains.

DIGESTIBILITY OF THE SORGHUM MEALS PREPARED AS MUSHES.

DIGESTION EXPERIMENTS WITH KAFIR MUSH.

To ascertain whether or not the method of cooking the sorghum meals influences their digestibility, the series of tests reported in the following pages was made. In these experiments kafir meal from the same lot as that used in the preceding tests was cooked as a mush (p. 5), which was eaten with a basal ration consisting of apple sauce, butter, sirup, and sugar. The diet proved entirely satisfactory for the tests, in that it was sufficiently appetizing to preclude any psychic dislike of the food, so that a nominal quantity of mush was willingly eaten. The same subjects cooperated in these tests and continued the same routine that was followed in the previous experiments.

The experimental data of three experiments with kafir mush are summarized in the following tables:

Data of digestion experiments with kafir mush in a simple mixed diet.

| | Weight. | Water. | Protein. | Fat. | Carbohy-
drates. | Ash. |
|--|---------|---------|----------|--------|---------------------|--------|
| | Grams. | Grams. | Grams. | Grams. | Grams. | Grams. |
| Experiment No. 239, subject D. G. G.: | | | | | | |
| Kafir mush..... | 3,299.0 | 2,415.9 | 130.0 | 1.3 | 698.1 | 53.7 |
| Apple sauce..... | 248.0 | 27.3 | 2.5 | 210.8 | | 7.4 |
| Butter..... | 1,617.0 | 681.0 | | | 936.0 | |
| Sirup..... | 135.0 | | | | 135.0 | |
| Sugar..... | | | | | | |
| Total food consumed..... | 5,299.0 | 3,124.2 | 132.5 | 212.1 | 1,769.1 | 61.1 |
| Feces..... | 119.0 | | 52.9 | 11.4 | 43.8 | 10.9 |
| Amount utilized..... | | | 79.6 | 200.7 | 1,725.3 | 50.2 |
| Digestibility of entire ration (per cent)..... | | | 60.1 | 94.6 | 97.5 | 82.2 |
| Estimated digestibility of mush alone
(per cent)..... | | | 59.4 | | 96.8 | |
| Experiment No. 240, subject R. L. S.: | | | | | | |
| Kafir mush..... | 3,282.0 | 2,403.4 | 129.3 | 1.3 | 694.5 | 53.5 |
| Apple sauce..... | 437.0 | 396.8 | 1.0 | 1.3 | 37.1 | .8 |
| Butter..... | 290.0 | 31.9 | 2.9 | 246.5 | | 8.7 |
| Sirup..... | 1,315.0 | 555.6 | | | 759.4 | |
| Sugar..... | 52.0 | | | | 52.0 | |
| Total food consumed..... | 5,376.0 | 3,387.7 | 133.2 | 249.1 | 1,543.0 | 63.0 |
| Feces..... | 119.0 | | 50.0 | 17.3 | 38.2 | 13.5 |
| Amount utilized..... | | | 83.2 | 231.8 | 1,504.8 | 49.5 |
| Digestibility of entire ration (per cent)..... | | | 62.5 | 93.1 | 97.5 | 78.6 |
| Estimated digestibility of mush alone
(per cent)..... | | | 61.5 | | 97.4 | |

Data of digestion experiments with kafir mush in a simple mixed diet—Continued.

| | Weight. | Water. | Protein. | Fat. | Carbohy-
drates. | Ash. |
|--|---------------|---------------|---------------|---------------|---------------------|---------------|
| Experiment No. 241, subject O. E. S.: | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> |
| Kafir mush..... | 3,089.0 | 2,262.1 | 121.7 | 1.2 | 653.6 | 50.4 |
| Apple sauce..... | 1,069.0 | 970.6 | 2.6 | 3.2 | 90.7 | 1.9 |
| Butter..... | 156.0 | 17.1 | 1.6 | 132.6 | ..... | 4.7 |
| Sirup..... | 1,580.0 | 669.7 | ..... | ..... | 910.3 | ..... |
| Sugar..... | 52.0 | ..... | ..... | ..... | 52.0 | ..... |
| Total food consumed..... | 5,946.0 | 3,919.5 | 125.9 | 137.0 | 1,706.6 | 57.0 |
| Feces..... | 196.0 | ..... | 93.5 | 17.7 | 65.9 | 18.9 |
| Amount utilized..... | ..... | ..... | 32.4 | 119.3 | 1,640.7 | 38.1 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 25.7 | 87.1 | 96.1 | 66.8 |
| Estimated digestibility of mush alone
(per cent)..... | | | 23.5 | | 94.2 | |
| Average food consumed per subject per
day..... | 1,846.8 | 1,159.1 | 43.5 | 66.5 | 557.6 | 20.1 |

Summary of digestion experiments with kafir mush in a simple mixed diet.

| Experi-
ment No. | Subject. | Protein. | Carbohy-
drates. |
|---------------------|--------------|------------------|---------------------|
| | | <i>Per cent.</i> | <i>Per cent.</i> |
| 239..... | D. G. G..... | 59.4 | 96.8 |
| 240..... | R. L. S..... | 61.5 | 97.4 |
| 241..... | O. E. S..... | 23.5 | 94.2 |
| | Average..... | 48.1 | 96.1 |

The results of the data tabulated above show that, while 96.1 per cent of the carbohydrate of kafir mush was digested, an average of only 48.1 per cent of the protein was available to the body. It was found that the mush supplied 42 grams of protein and 227 grams of carbohydrate per man per day.

DIGESTION EXPERIMENTS WITH FETERITA MUSH.

Feterita mush prepared in the manner already described formed a large part of the diet of the following experiments, and the same basal ration, consisting of apple sauce, butter, sirup, and sugar, was eaten with the mush. The following tables record the data of the digestion experiments.

Data of digestion experiments with feterita mush in a simple mixed diet.

| | Weight. | Water. | Protein. | Fat. | Carbohy-
drates. | Ash. |
|--|---------------|---------------|---------------|---------------|---------------------|---------------|
| Experiment No. 258, subject H. F. B.: | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> |
| Feterita mush..... | 2,915.0 | 1,929.1 | 131.2 | 8.7 | 803.7 | 42.3 |
| Apple sauce..... | 1,174.0 | 1,066.0 | 2.8 | 3.5 | 99.6 | 2.1 |
| Butter..... | 205.0 | 22.6 | 2.0 | 174.3 | ..... | 6.1 |
| Sirup..... | 1,346.0 | 350.0 | ..... | ..... | 996.0 | ..... |
| Sugar..... | 220.0 | ..... | ..... | ..... | 220.0 | ..... |
| Total food consumed..... | 5,860.0 | 3,367.7 | 136.0 | 186.5 | 2,119.3 | 50.5 |
| Feces..... | 53.0 | ..... | 29.6 | 4.4 | 15.0 | 4.0 |
| Amount utilized..... | ..... | ..... | 106.4 | 182.1 | 2,104.3 | 46.5 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 78.2 | 97.6 | 99.3 | 92.1 |
| Estimated digestibility of mush alone
(per cent)..... | | | 77.5 | | 99.3 | |

Data of digestion experiments with feterita mush in a simple mixed diet—Continued.

| | Weight. | Water. | Protein. | Fat. | Carbohy-
drates. | Ash. |
|--|---------------|---------------|---------------|---------------|---------------------|---------------|
| Experiment No. 259, subject D. G. G.: | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> |
| Feterita mush..... | 3,027.0 | 2,003.3 | 136.2 | 9.1 | 834.5 | 43.9 |
| Apple sauce..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Butter..... | 240.0 | 26.4 | 2.4 | 204.0 | ..... | 7.2 |
| Sirup..... | 1,258.0 | 327.1 | ..... | ..... | 930.9 | ..... |
| Sugar..... | 112.0 | ..... | ..... | ..... | 112.0 | ..... |
| Total food consumed..... | 4,637.0 | 2,356.8 | 138.6 | 213.1 | 1,877.4 | 51.1 |
| Feces..... | 150.0 | ..... | 76.9 | 16.8 | 43.3 | 13.0 |
| Amount utilized..... | ..... | ..... | 61.7 | 196.3 | 1,834.1 | 38.1 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 44.5 | 92.1 | 97.7 | 74.6 |
| Estimated digestibility of mush alone
(per cent)..... | | | 43.6 | | 97.3 | |
| Experiment No. 260, subject R. L. S.: | ..... | ..... | ..... | ..... | ..... | ..... |
| Feterita mush..... | 2,490.0 | 1,647.9 | 112.0 | 7.5 | 686.5 | 36.1 |
| Apple sauce..... | 853.0 | 774.5 | 2.1 | 2.6 | 72.3 | 1.5 |
| Butter..... | 203.0 | 22.3 | 2.0 | 172.6 | ..... | 6.1 |
| Sirup..... | 1,163.0 | 302.4 | ..... | ..... | 860.6 | ..... |
| Sugar..... | 33.0 | ..... | ..... | ..... | 33.0 | ..... |
| Total food consumed..... | 4,742.0 | 2,747.1 | 116.1 | 182.7 | 1,652.4 | 43.7 |
| Feces..... | 125.0 | ..... | 64.9 | 12.1 | 36.8 | 11.2 |
| Amount utilized..... | ..... | ..... | 51.2 | 170.6 | 1,615.6 | 32.5 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 44.1 | 93.4 | 97.8 | 74.4 |
| Estimated digestibility of mush alone
(per cent)..... | | | 42.1 | | 98.3 | |
| Experiment No. 261, subject O. E. S.: | ..... | ..... | ..... | ..... | ..... | ..... |
| Feterita mush..... | 2,825.0 | 1,869.6 | 127.1 | 8.5 | 778.8 | 41.0 |
| Apple sauce..... | 1,274.0 | 1,156.8 | 3.1 | 3.8 | 108.0 | 2.3 |
| Butter..... | 135.0 | 14.9 | 1.3 | 114.8 | ..... | 4.0 |
| Sirup..... | 1,658.0 | 431.1 | ..... | ..... | 1,226.9 | ..... |
| Sugar..... | 166.0 | ..... | ..... | ..... | 166.0 | ..... |
| Total food consumed..... | 6,058.0 | 3,472.4 | 131.5 | 127.1 | 2,279.7 | 47.3 |
| Feces..... | 162.0 | ..... | 88.5 | 18.8 | 41.8 | 12.9 |
| Amount utilized..... | ..... | ..... | 43.0 | 108.3 | 2,237.9 | 34.4 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 32.7 | 85.2 | 98.2 | 72.7 |
| Estimated digestibility of mush alone
(per cent)..... | | | 30.4 | | 99.6 | |
| Average food consumed per subject per
day..... | 1,774.7 | 995.3 | 43.5 | 59.1 | 660.7 | 16.1 |

Summary of digestion experiments with feterita mush in a simple mixed diet.

| Experi-
ment No. | Subject. | Protein. | Carbo-
hydrates. | Experi-
ment No. | Subject. | Protein. | Carbo-
hydrates. |
|---------------------|--------------|------------------|---------------------|---------------------|--------------|------------------|---------------------|
| 258..... | H. F. B..... | <i>Per cent.</i> | <i>Per cent.</i> | 261..... | O. E. S..... | <i>Per cent.</i> | <i>Per cent.</i> |
| 259..... | D. G. G..... | 77.5 | 99.3 | ..... | ..... | 30.4 | 99.6 |
| 260..... | R. L. S..... | 43.6 | 97.3 | ..... | Average..... | 48.4 | 98.6 |
| ..... | ..... | 42.1 | 98.3 | ..... | ..... | ..... | ..... |

In these experiments an average of 43.5 grams of protein was supplied by the total diet, and of this amount 42.2 grams, or about 97 per cent was derived from the feterita meal and 48.4 per cent digested. The carbohydrate portion of the mush, as in the other tests, was very completely utilized, since an average of 259 grams daily was 98.6 per cent digested.

DIGESTION EXPERIMENTS WITH MILO MUSH.

Milo mush closely resembled the other mushes in appearance and lack of definite flavor. Eaten with sirup and butter, however, it was apparently relished by the four subjects who assisted in the experiments recorded below:

Data of digestion experiments with milo mush in a simple mixed diet.

| | Weight. | Water. | Protein. | Fat. | Carbohy-
drates. | Ash. |
|--|---------------|---------------|---------------|---------------|---------------------|---------------|
| | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> |
| Experiment No. 254, subject H. F. B.: | | | | | | |
| Milo mush..... | 3,656.0 | 2,772.0 | 121.0 | 25.6 | 690.6 | 46.8 |
| Apple sauce..... | 1,021.0 | 927.1 | 2.4 | 3.1 | 86.6 | 1.8 |
| Butter..... | 277.0 | 30.5 | 2.8 | 235.4 | ..... | 8.3 |
| Sirup..... | 1,494.0 | 556.0 | ..... | ..... | 938.0 | ..... |
| Sugar..... | 209.0 | ..... | ..... | ..... | 209.0 | ..... |
| Total food consumed..... | 6,657.0 | 4,285.6 | 126.2 | 264.1 | 1,924.2 | 56.9 |
| Feces..... | 189.0 | ..... | 95.9 | 18.9 | 59.2 | 15.0 |
| Amount utilized..... | ..... | ..... | 30.3 | 245.2 | 1,865.0 | 41.9 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 24.0 | 92.8 | 96.9 | 73.6 |
| Estimated digestibility of mush alone
(per cent)..... | | | 21.2 | | 96.0 | |
| Experiment No. 255, subject D. G. G.: | | | | | | |
| Milo mush..... | 3,972.0 | 3,011.6 | 131.5 | 27.8 | 750.3 | 50.8 |
| Apple sauce..... | ..... | ..... | ..... | ..... | ..... | ..... |
| Butter..... | 249.0 | 27.4 | 2.5 | 211.6 | ..... | 7.5 |
| Sirup..... | 1,424.0 | 520.8 | ..... | ..... | 903.2 | ..... |
| Sugar..... | 129.0 | ..... | ..... | ..... | 129.0 | ..... |
| Total food consumed..... | 5,774.0 | 3,559.8 | 134.0 | 239.4 | 1,782.5 | 58.3 |
| Feces..... | 151.0 | ..... | 79.5 | 11.8 | 46.0 | 13.7 |
| Amount utilized..... | ..... | ..... | 54.5 | 227.6 | 1,736.5 | 44.6 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 40.7 | 95.1 | 97.4 | 76.5 |
| Estimated digestibility of mush alone
(per cent)..... | | | 39.5 | | 96.6 | |
| Experiment No. 256, subject R. L. S.: | | | | | | |
| Milo mush..... | 2,945.0 | 2,232.9 | 97.5 | 20.6 | 556.3 | 37.7 |
| Apple sauce..... | 744.0 | 675.6 | 1.8 | 2.2 | 63.1 | 1.3 |
| Butter..... | 201.0 | 22.1 | 2.0 | 170.9 | ..... | 6.0 |
| Sirup..... | 1,225.0 | 476.5 | ..... | ..... | 748.5 | ..... |
| Sugar..... | 20.0 | ..... | ..... | ..... | 20.0 | ..... |
| Total food consumed..... | 5,135.0 | 3,407.1 | 101.3 | 193.7 | 1,387.9 | 45.0 |
| Feces..... | 102.0 | ..... | 51.9 | 13.2 | 26.1 | 10.8 |
| Amount utilized..... | ..... | ..... | 49.4 | 180.5 | 1,361.8 | 34.2 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 48.8 | 93.2 | 98.1 | 76.0 |
| Estimated digestibility of mush alone
(per cent)..... | | | 47.2 | | 99.2 | |
| Experiment No. 257, subject O. E. S.: | | | | | | |
| Milo mush..... | 3,642.0 | 2,761.4 | 120.5 | 25.5 | 688.0 | 46.6 |
| Apple sauce..... | 1,087.0 | 987.0 | 2.6 | 3.2 | 92.2 | 2.0 |
| Butter..... | 166.0 | 18.2 | 1.7 | 141.1 | ..... | 5.0 |
| Sirup..... | 1,473.0 | 552.9 | ..... | ..... | 920.1 | ..... |
| Sugar..... | 206.0 | ..... | ..... | ..... | 206.0 | ..... |
| Total food consumed..... | 6,574.0 | 4,319.5 | 124.8 | 169.8 | 1,906.3 | 53.6 |
| Feces..... | 167.0 | ..... | 85.3 | 21.8 | 45.0 | 14.9 |
| Amount utilized..... | ..... | ..... | 39.5 | 148.0 | 1,861.3 | 38.7 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 31.7 | 87.2 | 97.6 | 72.2 |
| Estimated digestibility of mush alone
(per cent)..... | | | 29.6 | | 98.9 | |
| Average food consumed per subject per
day..... | 2,011.7 | 1,297.7 | 40.5 | 72.3 | 583.4 | 17.8 |

Summary of digestion experiments with milo mush in a simple mixed diet.

| Experiment No. | Subject. | Protein. | Carbohy-
drates. | Experiment No. | Subject. | Protein. | Carbohy-
drates. |
|----------------|--------------|------------------|---------------------|----------------|--------------|------------------|---------------------|
| | | <i>Per cent.</i> | <i>Per cent.</i> | | | <i>Per cent.</i> | <i>Per cent.</i> |
| 254..... | H. F. B..... | 21.2 | 96.0 | 257..... | O. E. S..... | 29.6 | 98.9 |
| 255..... | D. G. G..... | 39.5 | 96.6 | | | | |
| 256..... | R. L. S..... | 47.2 | 99.2 | | Average..... | 34.4 | 97.7 |

In the above summary it will be noted that an average of 97.7 per cent of the carbohydrates of milo mush was digested and that 34.4 per cent of the milo protein was assimilated by the body. This mush was apparently less digested than that of the preceding experiments and, moreover, it supplied only 39 grams of protein and 224 grams of carbohydrates daily.

DIGESTION EXPERIMENTS WITH KAOLIANG MUSH.

Kaoliang mush was of a light-chocolate color and so had a different appearance from that of the other mushes. Its flavor, however, was not pronounced, but much like that of the mushes made from the other grain sorghums studied. The essential data of eight digestion experiments in which four subjects assisted are recorded in the following tables:

Data of digestion experiments with kaoliang mush in a simple mixed diet.

| | Weight. | Water. | Protein. | Fat. | Carbohy-
drates. | Ash. |
|--|---------------|---------------|---------------|---------------|---------------------|---------------|
| Experiment No. 385, subject D. G. G.: | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> |
| Kaoliang mush..... | 3,060.0 | 2,400.9 | 82.3 | 27.9 | 527.5 | 21.4 |
| Apple sauce..... | 1,013.0 | 916.3 | 2.5 | 3.2 | 89.1 | 1.9 |
| Butter..... | 267.0 | 29.4 | 2.7 | 226.9 | ..... | 8.0 |
| Sirup..... | 1,586.0 | 634.4 | ..... | ..... | 951.6 | ..... |
| Sugar..... | 129.0 | ..... | ..... | ..... | 129.0 | ..... |
| Total food consumed..... | 6,055.0 | 3,981.0 | 87.5 | 258.0 | 1,697.2 | 31.3 |
| Feces..... | 166.0 | ..... | 85.9 | 19.2 | 47.1 | 13.8 |
| Amount utilized..... | ..... | ..... | 1.6 | 238.8 | 1,650.1 | 17.5 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 18.3 | 92.6 | 97.2 | 55.9 |
| Estimated digestibility of mush alone
(per cent)..... | | | | | 96.9 | |
| Experiment No. 386, subject A. J. H.: | | | | | | |
| Kaoliang mush..... | 2,388.0 | 1,873.6 | 64.3 | 21.7 | 411.7 | 16.7 |
| Apple sauce..... | 931.0 | 842.1 | 2.3 | 2.9 | 81.9 | 1.8 |
| Butter..... | 164.0 | 18.1 | 1.6 | 139.4 | ..... | 4.9 |
| Sirup..... | 479.0 | 191.6 | ..... | ..... | 287.4 | ..... |
| Sugar..... | 89.0 | ..... | ..... | ..... | 89.0 | ..... |
| Total food consumed..... | 4,051.0 | 2,925.4 | 68.2 | 164.0 | 870.0 | 23.4 |
| Feces..... | 149.0 | ..... | 82.0 | 21.4 | 32.1 | 13.5 |
| Amount utilized..... | ..... | ..... | ..... | 142.6 | 837.9 | 9.9 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | ..... | 87.0 | 96.3 | 42.3 |
| Estimated digestibility of mush alone
(per cent)..... | | | | | 96.0 | |

Data of digestion experiments with kaoliang mush in a simple mixed diet—Continued.

| | Weight. | Water. | Protein. | Fat. | Carbohy-
drates. | Ash. |
|--|---------------|---------------|---------------|---------------|---------------------|---------------|
| Experiment No. 387, subject R. L. S.: | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> |
| Kaoliang mush..... | 2,849.0 | 2,235.3 | 76.6 | 25.9 | 491.2 | 20.0 |
| Apple sauce..... | 1,024.0 | 926.2 | 2.6 | 3.2 | 90.1 | 1.9 |
| Butter..... | 260.0 | 28.6 | 2.6 | 221.0 | ..... | 7.8 |
| Sirup..... | 396.0 | 158.4 | ..... | ..... | 237.6 | ..... |
| Sugar..... | 46.0 | ..... | ..... | ..... | 46.0 | ..... |
| Total food consumed..... | 4,575.0 | 3,348.5 | 81.8 | 250.1 | 864.9 | 29.7 |
| Feces..... | 155.0 | ..... | 85.3 | 19.5 | 36.3 | 13.9 |
| Amount utilized..... | ..... | ..... | ..... | 230.6 | 828.6 | 15.8 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | ..... | 92.2 | 95.8 | 53.2 |
| Estimated digestibility of mush alone
(per cent)..... | | | | | 95.6 | |
| Experiment No. 388, subject O. E. S.: | | | | | | |
| Kaoliang mush..... | 2,510.0 | 1,969.4 | 67.5 | 22.8 | 432.7 | 17.6 |
| Apple sauce..... | 1,008.0 | 911.8 | 2.5 | 3.1 | 88.7 | 1.9 |
| Butter..... | 151.0 | 16.6 | 1.5 | 128.4 | ..... | 4.5 |
| Sirup..... | 1,128.0 | 451.2 | ..... | ..... | 676.8 | ..... |
| Sugar..... | 172.0 | ..... | ..... | ..... | 172.0 | ..... |
| Total food consumed..... | 4,969.0 | 3,349.0 | 71.5 | 154.3 | 1,370.2 | 24.0 |
| Feces..... | 163.0 | ..... | 83.8 | 20.9 | 42.6 | 15.7 |
| Amount utilized..... | ..... | ..... | ..... | 133.4 | 1,327.6 | 8.3 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | ..... | 86.5 | 96.9 | 34.6 |
| Estimated digestibility of mush alone
(per cent)..... | | | | | 96.1 | |
| Experiment No. 397, subject D. G. G.: | | | | | | |
| Kaoliang mush..... | 2,831.0 | 2,036.1 | 109.7 | 26.3 | 629.5 | 29.4 |
| Apple sauce..... | 830.0 | 756.5 | 1.9 | 2.4 | 67.8 | 1.4 |
| Butter..... | 175.0 | 19.2 | 1.7 | 148.8 | ..... | 5.3 |
| Sirup..... | 1,266.0 | 506.4 | ..... | ..... | 759.6 | ..... |
| Sugar..... | 108.0 | ..... | ..... | ..... | 108.0 | ..... |
| Total food consumed..... | 5,210.0 | 3,318.2 | 113.3 | 177.5 | 1,564.9 | 36.1 |
| Feces..... | 199.0 | ..... | 110.3 | 21.6 | 51.2 | 15.9 |
| Amount utilized..... | ..... | ..... | 3.0 | 155.9 | 1,513.7 | 20.2 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 2.6 | 87.8 | 96.7 | 56.0 |
| Estimated digestibility of mush alone
(per cent)..... | | | | | 95.7 | |
| Experiment No. 398, subject A. J. H.: | | | | | | |
| Kaoliang mush..... | 1,988.0 | 1,429.8 | 77.0 | 18.5 | 442.0 | 20.7 |
| Apple sauce..... | 653.0 | 595.1 | 1.5 | 1.9 | 53.4 | 1.1 |
| Butter..... | 208.0 | 22.9 | 2.1 | 176.8 | ..... | 6.2 |
| Sirup..... | 253.0 | 101.2 | ..... | ..... | 151.8 | ..... |
| Sugar..... | 54.0 | ..... | ..... | ..... | 54.0 | ..... |
| Total food consumed..... | 3,156.0 | 2,149.0 | 80.6 | 197.2 | 701.2 | 28.0 |
| Feces..... | 131.0 | ..... | 71.7 | 17.4 | 30.1 | 11.8 |
| Amount utilized..... | ..... | ..... | 8.9 | 179.8 | 671.1 | 16.2 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 11.0 | 91.2 | 95.7 | 57.9 |
| Estimated digestibility of mush alone
(per cent)..... | | | 7.3 | | 95.3 | |
| Experiment No. 399, subject R. L. S.: | | | | | | |
| Kaoliang mush..... | 2,822.0 | 2,029.6 | 109.4 | 26.2 | 627.5 | 29.3 |
| Apple sauce..... | 760.0 | 692.7 | 1.7 | 2.2 | 62.1 | 1.3 |
| Butter..... | 341.0 | 37.5 | 3.4 | 289.9 | ..... | 10.2 |
| Sirup..... | 716.0 | 286.4 | ..... | ..... | 429.6 | ..... |
| Sugar..... | 40.0 | ..... | ..... | ..... | 40.0 | ..... |
| Total food consumed..... | 4,679.0 | 3,046.2 | 114.5 | 318.3 | 1,159.2 | 40.8 |
| Feces..... | 160.0 | ..... | 86.4 | 22.7 | 36.0 | 14.9 |
| Amount utilized..... | ..... | ..... | 28.1 | 295.6 | 1,123.2 | 25.9 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 24.5 | 92.9 | 96.9 | 63.5 |
| Estimated digestibility of mush alone
(per cent)..... | | | 21.4 | | 96.7 | |

Data of digestion experiments with kaoliang mush in a simple mixed diet—Continued.

| | Weight. | Water. | Protein. | Fat. | Carbohy-
drates. | Ash. |
|--|---------------|---------------|---------------|---------------|---------------------|---------------|
| Experiment No. 400, subject O. E. S.: | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> | <i>Grams.</i> |
| Kaoliang mush..... | 2,146.0 | 1,543.4 | 83.2 | 20.0 | 477.1 | 22.3 |
| Apple sauce..... | 742.0 | 676.2 | 1.7 | 2.2 | 60.6 | 1.3 |
| Butter..... | 198.0 | 21.8 | 2.0 | 168.3 | ..... | 5.9 |
| Sirup..... | 1,036.0 | 414.4 | ..... | ..... | 621.6 | ..... |
| Sugar..... | 192.0 | ..... | ..... | ..... | 192.0 | ..... |
| Total food consumed..... | 4,314.0 | 2,655.8 | 86.9 | 190.5 | 1,351.3 | 29.5 |
| Feces..... | 154.0 | ..... | 78.2 | 26.1 | 35.4 | 14.3 |
| Amount utilized..... | ..... | ..... | 8.7 | 164.4 | 1,315.9 | 15.2 |
| Digestibility of entire ration (per cent)..... | ..... | ..... | 10.0 | 86.3 | 97.4 | 51.5 |
| Estimated digestibility of mush alone
(per cent)..... | | | 6.5 | | 97.4 | |
| Average food consumed per subject
per day..... | 1,542.0 | 1,032.2 | 29.3 | 71.3 | 399.1 | 10.1 |

Summary of digestion experiments with kaoliang mush in a simple mixed diet.

| Experi-
ment No. | Subject. | Protein. | Carbohy-
drates. | Experi-
ment No. | Subject. | Protein. | Carbohy-
drates. |
|---------------------|--------------|------------------|---------------------|---------------------|--------------|------------------|---------------------|
| | | <i>Per cent.</i> | <i>Per cent.</i> | | | <i>Per cent.</i> | <i>Per cent.</i> |
| 385..... | D. G. G..... | ..... | 96.9 | 398..... | A. J. H..... | 7.3 | 95.3 |
| 386..... | A. J. H..... | ..... | 96.0 | 399..... | R. L. S..... | 21.4 | 96.7 |
| 387..... | R. L. S..... | ..... | 95.6 | 400..... | O. E. S..... | 6.5 | 97.4 |
| 388..... | O. E. S..... | ..... | 96.1 | | | | |
| 397..... | D. G. G..... | ..... | 95.7 | | Average..... | 4.4 | 96.2 |

The digestibility of the kaoliang protein was found by averaging the eight experiments to be only 4.4 per cent, although the carbohydrate from this source was 96.2 per cent digested; 28 grams of protein and 168 grams of carbohydrate per man per day were supplied by the kaoliang mush. As the subjects reported that they were in normal physical condition during these experiments, it seems reasonable to attribute the incomplete digestibility of the kaoliang protein to the structure of the grain rather than to the chemical nature of the protein molecule. In view of the lack of information, however, regarding the histology of kaoliang and the other grain sorghums, it is difficult at the present time to explain conclusively the differences found for the digestibility of the protein constituent of these cereals.

SUMMARY OF DATA ON THE DIGESTIBILITY OF THE GRAIN-SORGHUM MUSHES.

The results of the experiments with the sorghum mushes show that 48 per cent, 48 per cent, 34 per cent, and 4 per cent of the cereal protein furnished by the rations containing dwarf kafir, feterita, dwarf milo, and kaoliang, respectively, are the estimated values for the digestibility of the protein constituent of the grains. Since these values were determined by as direct a method as is available—98 to 99 per cent of the total protein of the diet was obtained from the

grains—they may be considered to represent the digestibility of protein determined directly rather than estimated. The carbohydrate portion of the diet was as well assimilated as in the ordinary mixed diet, indicating that the very incomplete digestibility of protein was not due to faulty experimental methods. The diet proved to be entirely satisfying, at least for the three-day period, for the subjects reported that they were in normal physical condition throughout the experiments.

Comparing the experiments in which mush was eaten with those in which sorghum gingerbread formed the major portion of the diet, it was found that an average of 41 grams of protein per man per day was supplied in the former and 35 grams in the latter series of experiments. The explanation of such a small consumption of protein lies in the fact that the grain sorghums contain too little protein to make it feasible to obtain, say, 100 grams of protein daily on a diet of this nature. The amounts of energy supplied by the mush and bread diets were 3,000 and 2,850 calories, respectively, an energy value in agreement with the requirements of accepted dietary standards.

SUMMARY AND CONCLUSIONS.

In the experiments in which hard kafir bread was eaten with milk it was found that the protein of this cereal, as distinguished from that of the diet as a whole, was 58 per cent digested. Possibly owing to the large proportion of milk protein in the diet this value for the cereal protein alone may be too high.

In the majority of the experiments the grains under consideration were eaten in the form of softer bread than that mentioned above and also in the form of mushes. Considering the grain sorghums studied the results show that on an average the protein of the softer dwarf kafir bread, as distinguished from the protein of the diet as a whole, was 51 per cent digested and that of the dwarf kafir mush 48 per cent. In the case of the protein of feterita the values were 51 per cent for the bread protein and 48 per cent for the mush protein. With the dwarf milo the values were 40 per cent for the protein of the bread and 34 per cent for that of the mush, and for the kaoliang 20 per cent for the protein of the bread and 4 per cent for that of the mush.

Fat was present in these grains in very small and relatively unimportant quantities and so no attempt was made to estimate the digestibility of this constituent as supplied by the cereals.

In all cases it was found that the carbohydrates of the experimental rations and of the sorghums alone were very completely utilized. Considering the grain only, as distinguished from the ration as a whole, the average value for the dwarf kafir (hard) bread was 98 per cent, for softer dwarf kafir bread 96 per cent, and for dwarf kafir mush 96 per cent. In the case of carbohydrates supplied by feterita, the

average values were 97 per cent for the bread and 99 per cent for the mush; with dwarf milo 96 per cent for the bread and 98 per cent for the mush; and for kaoliang 96 per cent for both bread and mush.

The corn and wheat proteins, in general, were found to be somewhat less thoroughly digested than has usually been found to be the case with these cereals, this being due, no doubt, to the coarseness of the meals used. The average digestibility of the corn-bread protein, as distinguished from that of the diet as a whole, was 60 per cent and of the coarse wheat-bread protein 77 per cent. In the case of the carbohydrates 96 per cent of the total supplied by the corn bread, as distinguished from the diet as a whole, was digested and of the coarse wheat bread 95 per cent.

The experiments with all the grains were conducted under conditions as nearly uniform as possible, with the idea of getting directly comparable results. Hence it may be concluded that the protein of the grain sorghums is less digestible than that contained in either corn or wheat.

The discussion so far has concerned the experimental data principally from a technical standpoint, but the practical application of the results is certainly of equal interest. From the data here recorded and elsewhere available regarding the preparation of the sorghums for the table, it seems fair to conclude that these cereals are decidedly valuable as human food. They can be prepared for the table in palatable form, requiring, however, some special method of cooking to insure their being at their best. In preparing them it is most important to make certain of the absorption of water in such quantities that the particles of meal which are characteristically hard or flinty may be well softened.

To many palates the grain sorghums more nearly resemble buckwheat in flavor than they do corn or wheat. The flavor is quite generally regarded as agreeable, and the grains are conceded to be wholesome. Though their protein is less completely assimilated than that of corn or wheat, they are nevertheless, with the exception of kaoliang, a fairly good source of this nutrient. Furthermore, the sorghums are a good source of carbohydrate and furnish this important food constituent in a form very completely available to the body. The use of the grain sorghums in general offers variety to the diet, and in regions where other cereals are not so successfully grown they may contribute materially to the supply of materials suitable as human food.

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EGGS AND THEIR VALUE AS FOOD.

By C. F. LANGWORTHY, *Chief, Office of Home Economics.*

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INTRODUCTION.

Perhaps no article of diet of animal origin is more commonly eaten in all countries or served in a greater variety of ways than eggs. Hens' eggs are most common, although the eggs of domestic poultry other than hens are sometimes used. Guinea eggs are eaten where they are readily obtained and are much prized for their delicate flavor. Turkey eggs are mild in flavor and are eaten to some extent, though they are usually too valuable for hatching to be much used as food. Ducks' eggs are stronger or more pronounced in flavor than hens' eggs, the feed apparently exercising considerable influence on the flavor, but they are much liked by many and are now used more than formerly. Goose eggs are still stronger in flavor. Nevertheless, they have some use for table purposes, especially in regions where goose raising is common. In South Africa, where ostrich raising is an important industry, the eggs are used as food to some extent and are regarded as of excellent quality for cookery. Their food value is also recognized in those regions of the United States where ostriches are raised.

NOTE.—This bulletin is of special interest to housekeepers and to home-economics extension workers, teachers, and students. It summarizes data regarding the nature and uses of eggs and the effects of methods of handling, storing, and marketing upon the value of eggs in the household.

The eggs of wild birds, once commonly used, are still eaten, but in a limited way. Plovers' eggs are prized by epicures and the eggs of certain kinds of sea birds have been used to some extent.¹

Other eggs besides those of birds are also eaten. Turtles' eggs are generally highly prized and very commonly eaten where they can be obtained. The eggs of the terrapin are served with the flesh in some of the dishes prepared from it. Fish eggs, especially those of sturgeon, are eaten in large quantities preserved with salt, under the name of caviar. Shad roe is another illustration of the use of fish eggs.

Notwithstanding these minor instances, the term "eggs," when used in connection with food topics, refers to the eggs of birds, usually domestic poultry, and more particularly hens' eggs, and, unless qualified in some way, is used in the last sense in this bulletin.

Although man has been guided by instinct and experience in the selection of eggs for food and of birds for domestication as egg producers, he has nevertheless chosen kinds having distinct physiological characteristics. In this respect birds may be divided into two groups: (1) Those in which the young are hatched full-fledged and ready in a great measure to care for themselves, and (2) those in which the young are hatched unfledged and remain entirely dependent upon the parents for some time. Hens and guinea fowls are familiar examples of the first group; robins and sparrows of the second. The eggs of the two classes differ materially in composition, as might be expected from the rôle they play in the development of the young bird, more nutritive material being needed in the first case than in the second, since growth is continued in the egg until the bird reaches a more advanced stage of development. It is interesting to note that the first includes the birds whose eggs are economically important.

The appearance of an egg—the shell with its lining of membrane inclosing the white and the yolk—is too familiar to need any discussion. Each fertile egg contains a germ, or embryo, and is at the same time a storehouse of material for the development and growth of the young individual until it has reached such a stage that life is possible outside the narrow limits of the shell. The embryo is in close relationship with the yolk, which furnishes the nutritive material for its early development, the white being used later. Naturally, yolk and white differ in composition as much as they do in appearance, their food value for man corresponding to the part they play in the growth of the chick.

¹ The danger of exterminating these desirable birds by gathering their eggs for food has been discussed in U. S. Dept. Agr. Yearbook, 1899, p. 270.

DESCRIPTION AND COMPOSITION OF EGGS.

SIZE.

The eggs of different kinds of domestic poultry vary in size as well as appearance, and there is also a considerable range in the size of eggs of different breeds; thus, hens' eggs range from the small ones laid by bantams to the large ones laid by such breeds as Light Brahmas. On an average, hens' eggs are 2.27 inches in length and 1.72 inches in diameter, or width, at the broadest point, and weigh about 2 ounces each, or 8 eggs to the pound (1.5 pounds per dozen). Generally speaking, the eggs of pullets are smaller than those of old birds, those of guinea fowls about two-thirds the size of hens' eggs, those of ducks somewhat larger, while those of turkeys and geese are considerably larger.

COLOR OF EGGS AND ITS RELATION TO THEIR VALUE AND USE.

Considering both wild and domestic birds of all sorts, the eggshell ranges from white to deep colors through a variety of tints and mottlings. The eggs of domestic fowls are not highly colored. Those of hens vary from white to a light or deep brownish tint, the eggs from a particular breed being very similar as regards their color, though varying in depth of color or shade. The eggs of ducks are bluish white; those of geese, commonly white; those of guinea fowls, white or light brown, more or less mottled with a deeper shade; and those of turkeys, usually speckled with a yellowish brown.

Any special coloring in the eggs of wild birds is commonly explained as a protective measure which has been developed to render the eggs inconspicuous in their normal surroundings and therefore less easily found by their enemies. Such reasoning would indicate that the observed differences in the color of hens' eggs are due to characteristics which different breeds have inherited from remote wild ancestors. Of common breeds, for example, Cochins, Brahmas, and Langshans, all belonging to the Asiatic class, lay brown-shelled eggs, while Leghorns and Minorcas, which belong to the Mediterranean class, lay white-shelled eggs.

The color of the shells, whatever its reason, is a feature which has some effect on the market value of eggs of domestic poultry, although not upon their food value (see pp. 4 and 6), the brown-shelled eggs bringing the higher price, for instance, in the Boston market, and the white-shelled eggs in the New York market. In England the preference is decidedly in favor of the tinted eggs. Such local differences probably originated in the fact that some one breed of hens was once chiefly used in a given region and its type of eggs set the standard there.

Extended investigations at some of the agricultural experiment stations, in which many analyses were made of eggs from different kinds of hens, have shown plainly that there are no uniform variations in the physical properties and chemical composition of brown-shelled as compared with white-shelled eggs. Such tests justify the statement that the eggs of any given breed of hens, whatever the color of the shells, are, on an average, as nutritious as those of another breed, provided the eggs are of the same size and freshness and the fowls are equally well fed.

The color of the egg contents is also a matter of interest with respect to market value and domestic uses. Raw egg white has a more or less greenish tinge, which is apparently influenced somewhat by the character of the feed, though no specific coloring matter has been isolated from it. When the albumin is coagulated by heat in cooking, the color varies from white to pale greenish or yellowish tones, hard to define, yet distinct. There is a belief that eggs with shells of the same color should show the same color in the cooked whites and that the cooked albumin of white-shelled eggs is decidedly whiter than that of eggs with tinted shells. Perhaps few persons carry preferences so far as to refuse an egg because of the color of the white, yet it is stated on good authority that in high-class hotels and restaurants, where great attention is paid to details, it has been found that the boiled eggs served must match in color. If, when taken from the shell, one is greenish white and the other clear white, the eggs are often rejected on the ground that one of them is not of the required standard of excellence.

The egg yolk owes its characteristic yellow color to a pigment whose chemical nature has been carefully studied. The depth of the yellow color apparently depends—in large measure, at least—upon the presence of green feed in the ration, and pale-colored yolks indicate that such feed is deficient. Though frequently the yolk is pale, the color which we commonly regard as a standard is a decided yellow, and so the pale-yolked eggs are often said by housekeepers to be inferior, as a given number of such yolks impart to cake or custard less of the yellow color regarded as an indication of richness than do eggs of a darker yolk, a belief which chemical analysis does not justify.

Although, as stated above, variations in color do not imply variations in food value, it is not at all unlikely that there are differences in flavor corresponding to the color of the egg yolk, that which is deep yellow having a more pronounced flavor than the pale one. At any rate, as long as preference for deep-colored yolks and pale whites exists, the poultry raiser who caters to a fancy market should take such factors into account.

FLAVOR OF EGGS AND FACTORS AFFECTING IT.

It is generally conceded that eggs which are perfectly fresh have the finest flavor. After they have been kept for a time, the flavor deteriorates, even if there is no indication of spoiling. Such differences are especially important when eggs are used for table purposes. Stale eggs are not regarded as palatable, and the flavor of spoiled eggs is such that for this, if for no other reason, they are totally unfit for food. The flavor of even perfectly fresh eggs is not always satisfactory, since it is influenced more or less by the character of the food eaten by the laying hens, eggs produced on highly nitrogenous rations, for instance, being inferior to those from a carbonaceous ration. Highly flavored food, such as wild-onion tops and cabbage, may also have a bad effect on the flavor of the eggs produced. This is a matter of importance, especially when poultry is kept to supply eggs for table use.

COMPOSITION.

The shell of a hen's egg constitutes about 11 per cent, the yolk 32 per cent, and the white 57 per cent of the total weight of the egg. The shell of a duck's egg constitutes about 14 per cent of the total weight and that of a plover's egg 10 per cent. The proportion of white and yolk varies somewhat with different breeds of hens, the proportion of yolk being greatest in bantam eggs and, in general, greater with those breeds which are best suited for fattening than with others. Brown-shelled eggs have been found to have a somewhat heavier shell than white-shelled eggs.

The following table shows the composition of hens' eggs (raw and cooked, brown shelled and white shelled) and of egg white and yolk, as well as the composition of the eggs (whole egg, white, and yolk) of guinea fowls, ducks, geese, turkeys, plovers, etc., and that of evaporated eggs and egg substitutes. For purposes of comparison the composition of several other familiar foods is also included.

Average composition of eggs, egg products, and certain other foods.

| | Refuse. | Water. | Protein. | Fat. | Carbohy-
drates. | Ash. | Fuel
value per
pound. ¹ |
|--|------------------|------------------|------------------|------------------|---------------------|------------------|--|
| | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Per cent.</i> | <i>Calories.</i> |
| Hen: | | | | | | | |
| Whole egg as purchased..... | 11.2 | 65.5 | 11.9 | 9.3 | ----- | 0.9 | 595 |
| Whole egg, edible portion..... | ----- | 73.7 | 13.4 | 10.5 | ----- | 1.0 | 670 |
| White..... | ----- | 86.2 | 12.3 | .2 | ----- | .6 | 230 |
| Yolk..... | ----- | 49.5 | 15.7 | 33.3 | ----- | 1.1 | 1,645 |
| Whole egg boiled, edible por-
tion..... | ----- | 73.2 | 13.2 | 12.0 | ----- | .8 | 730 |
| Duck: | | | | | | | |
| Whole egg as purchased..... | 13.7 | 60.8 | 12.1 | 12.5 | ----- | .8 | 730 |
| Whole egg, edible portion..... | ----- | 70.5 | 13.3 | 14.5 | ----- | 1.0 | 835 |
| White..... | ----- | 87.0 | 11.1 | .03 | ----- | .8 | 200 |
| Yolk..... | ----- | 45.8 | 16.8 | 36.2 | ----- | 1.2 | 1,785 |
| Goose: | | | | | | | |
| Whole egg as purchased..... | 14.2 | 59.7 | 12.9 | 12.3 | ----- | .9 | 755 |
| Whole egg, edible portion..... | ----- | 69.5 | 13.8 | 14.4 | ----- | 1.0 | 840 |
| White..... | ----- | 86.3 | 11.6 | .02 | ----- | .8 | 210 |
| Yolk..... | ----- | 44.1 | 17.3 | 36.2 | ----- | 1.3 | 1,790 |
| Turkey: | | | | | | | |
| Whole egg as purchased..... | 13.8 | 63.5 | 12.2 | 9.7 | ----- | .8 | 615 |
| Whole egg, edible portion..... | ----- | 73.7 | 13.4 | 11.2 | ----- | .9 | 700 |
| White..... | ----- | 86.7 | 11.5 | .03 | ----- | .8 | 210 |
| Yolk..... | ----- | 48.3 | 17.4 | 32.9 | ----- | 1.2 | 1,660 |
| Guinea fowl: | | | | | | | |
| Whole egg as purchased..... | 16.9 | 60.5 | 11.9 | 9.9 | ----- | .8 | 620 |
| Whole egg, edible portion..... | ----- | 72.8 | 13.5 | 12.0 | ----- | .9 | 735 |
| White..... | ----- | 86.6 | 11.6 | .03 | ----- | .8 | 210 |
| Yolk..... | ----- | 49.7 | 16.7 | 31.8 | ----- | 1.2 | 1,600 |
| Plover: | | | | | | | |
| Whole egg as purchased ² | 9.6 | 67.3 | 9.7 | 10.6 | ----- | .9 | 610 |
| Whole egg, edible portion ² | ----- | 74.4 | 10.7 | 11.7 | ----- | 1.0 | 670 |
| Fresh-water turtle eggs ² | ----- | 65.0 | 18.1 | 11.1 | ----- | 2.9 | 780 |
| Sea-turtle eggs ² | ----- | 76.4 | 18.8 | 9.8 | ----- | .4 | 740 |
| Salted duck eggs ² | ----- | 68.0 | 12.0 | 9.2 | ----- | 4.0 | 595 |
| Desiccated hens' eggs: | | | | | | | |
| Whole egg..... | ----- | 6.4 | 46.9 | 36.0 | 7.1 | 3.6 | 2,450 |
| White..... | ----- | 11.7 | 73.2 | .3 | 8.6 | 6.2 | 1,495 |
| Yolk..... | ----- | 5.9 | 33.3 | 51.6 | 5.7 | 3.5 | 2,815 |
| Egg substitute..... | ----- | 11.4 | 73.9 | .3 | 5.3 | 9.1 | 1,450 |
| Pudding (custard) powders ² | ----- | 13.0 | 2.1 | 3.4 | 80.9 | .6 | 1,645 |
| Shad roe..... | ----- | 71.2 | 20.9 | 3.8 | 2.6 | 1.5 | 580 |
| Caviar ² | ----- | 48.0 | 29.3 | 14.0 | 1.3 | 7.4 | ³ 1,125 |
| Cheese (full cream) as purchased..... | ----- | 34.2 | 25.9 | 33.7 | 2.4 | 3.8 | 1,890 |
| Sirloin steak as purchased..... | 12.8 | 54.0 | 16.5 | 16.1 | ----- | .9 | 955 |
| Sirloin steak, edible portion..... | ----- | 61.9 | 18.9 | 18.5 | ----- | 1.0 | 1,100 |
| Milk..... | ----- | 87.0 | 3.3 | 4.0 | 5.0 | .7 | 315 |
| Oysters, edible portion..... | ----- | 86.9 | 6.2 | 1.2 | 3.7 | 2.0 | 230 |
| Wheat flour..... | ----- | 12.0 | 11.4 | 1.0 | 75.1 | .5 | 1,610 |
| Potatoes as purchased..... | 20.0 | 62.6 | 1.8 | .1 | 14.7 | .8 | 305 |
| Potatoes, edible portion..... | ----- | 78.3 | 2.2 | .1 | 18.4 | 1.0 | 380 |

¹ These values were calculated on the assumption that protein and carbohydrates (each) yield 1,820 (or 4 calories per gram) calories per pound; and fat, 4,080 (or 9 calories per gram) calories per pound.

² European analyses.

³ Including 6.2 per cent common salt.

The above figures represent average values. Individual specimens vary more or less from the average.

As shown by analysis, eggs consist chiefly of two nutrients, protein and fat, in addition to water and mineral matter, or ash. Carbohydrates, valuable in the diet as a source of energy, are present in such small amounts that they are usually not determined in analysis—ducks' eggs containing only 0.3 per cent, hens' eggs 0.67 per cent, turkeys' and guinea fowls' eggs 0.8 per cent each, and goose eggs 1.3 per cent. An exception is found in the case of plovers' eggs, which have been reported to contain over 2 per cent. As regards distribution, about one-third of the carbohydrates occur in the

yolk and two-thirds in the white. The most abundant nutrient is protein or nitrogenous matter, of which three-fifths of the total is present in the white and two-fifths in the yolk. Protein supplies nitrogen needed to build and repair the body tissue, and also some energy, being equal to carbohydrate in this respect, although inferior to fat, as noted on page 9.

It is sometimes convenient to consider the relations of protein and energy in a definite amount of foodstuffs. In the case of a whole egg, 2.4 ounces of the edible portion would be required to supply 100 calories of energy, of which the protein would contribute 36 calories. Of white, 6.9 ounces would be needed to supply 100-calories, and of this amount 97 calories would be contributed by protein. In case of the yolk, 1 ounce will supply 100 calories, of which protein contributes 17.

Mineral matter is required by the body for building bone and other tissue and for regulating the body processes. In addition, recent research has shown that certain accessory substances (so-called vitamins, for example) are also present, which are required by the body in at least minute amounts. Since eggs contribute to all these body needs, their value as food is evident.

In composition eggs resemble such animal foods as meat, milk, and cheese, more than such vegetable foods as flour and potatoes. As will be seen by the figures in the above table, hens' eggs and those of other poultry do not differ greatly in composition. Furthermore, there is practically no significant difference in composition between hens' eggs with dark shells and those with white shells, although there is a popular belief in some localities that the former are richer. Neither does the cooked egg vary materially in composition from the raw, though it varies markedly in texture. The yolk and the white, on the other hand, differ greatly in composition, the yolk containing considerable fat and ash, and the white being practically free from fat and containing somewhat less protein and ash and considerably more water than the yolk. Though both yolk and white, when raw, are fluid, they are not thought of as containing water any more than other familiar foods in which water is not visible as such but combined or mingled with the other constituents so that the whole food is more or less moist, liquid, or juicy. This and similar facts are brought out in figure 1, which shows in diagrammatic form the composition of eggs and egg products.

Though eggs are conceded to be a nutritious food, they are less concentrated, that is, they contain more water than some—cheese, for instance. On the other hand, they are more concentrated than many others, milk or oysters, for instance, and on the whole do not differ greatly in this respect from lean meat. Their general resemblance in composition to other common animal foods suggests that

they may be properly used in the diet in the same way, an idea confirmed by almost universal experience. Such facts are brought out in figure 2, which compares eggs and a number of other common foods.

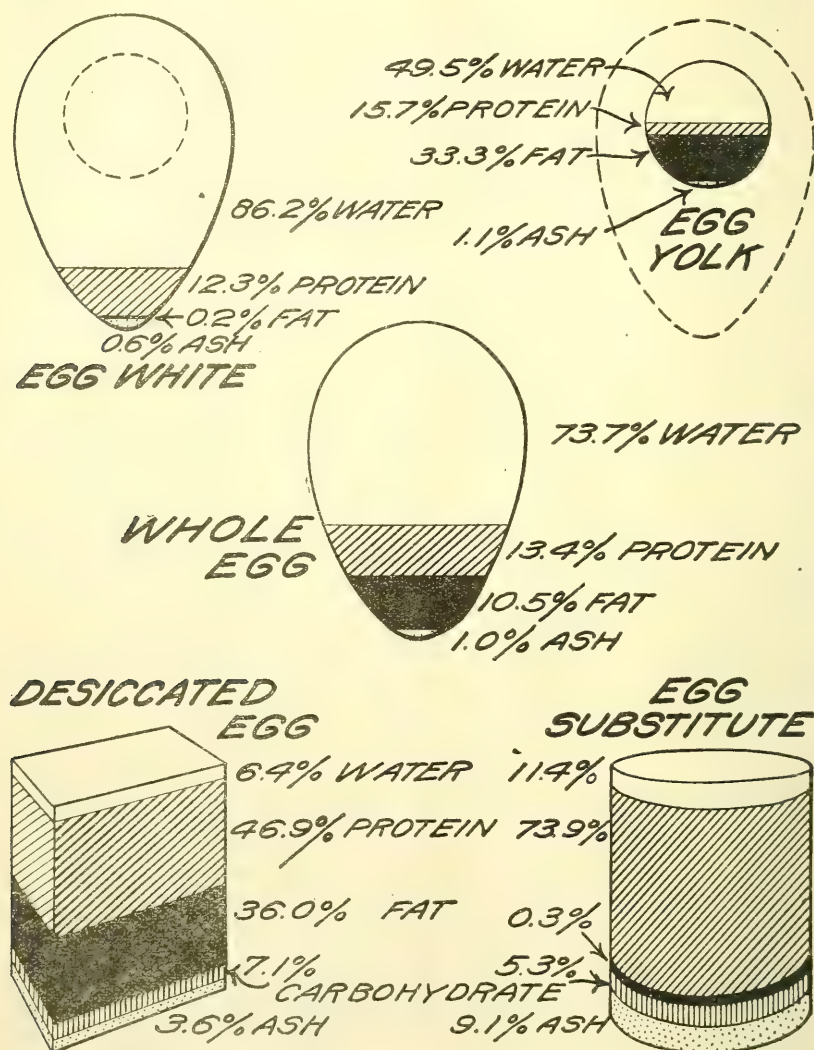


FIG. 1.—Chemical composition of egg yolk, egg white, desiccated egg, and egg substitute.

As sources of energy in the diet, eggs supply per pound a larger number of calories (the common heat unit) than does milk, and fewer than does beefsteak or white bread. This and other facts regarding the energy value of eggs and egg products as compared with some other foods are shown graphically in figure 3. A pound of egg yolk has a much higher energy value than a pound of egg

white, as will be understood when it is recalled that it is the yolk which contains the egg fat and that this constituent has an energy value per pound two and one-fourth times as great as either protein or carbohydrates. Egg yolk approaches full-cream cheese in energy value and has about two-thirds the energy value per pound of bacon, one of the common foods which are characterized by a very high fat content. Desiccated egg, as is the general rule with foods which

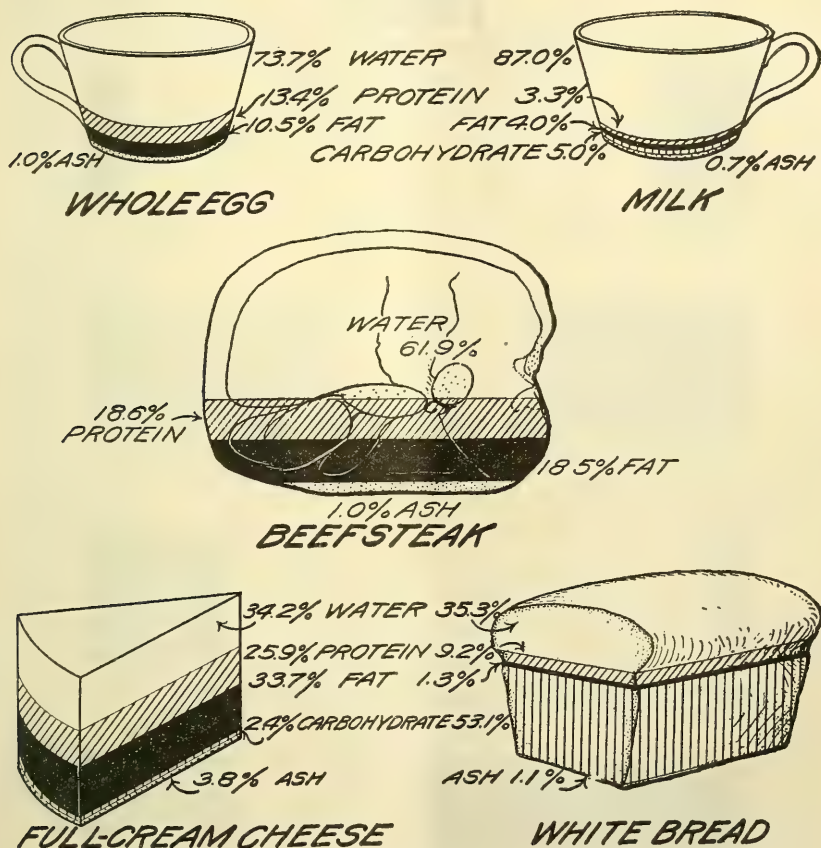


FIG. 2.—Chemical composition of eggs as compared with that of some other common foods.

have been concentrated by the evaporation of water, has a much higher energy value per pound than the fresh eggs.

As regards the specific nature of the different nutrients in eggs, much information is available. Egg white, formerly said to be pure albumin, is now known to contain, in addition to small amounts of carbohydrates, two distinct forms of albumin and a very little mineral matter, chiefly sodium chlorid (common salt). Phosphorus is also present, the amount being equivalent to about 0.03 per cent phosphoric acid.

A very extended investigation of the white of egg was made at the Connecticut State Experiment Station. The "albumen" or protein

STANDARD FOR COMPARISON

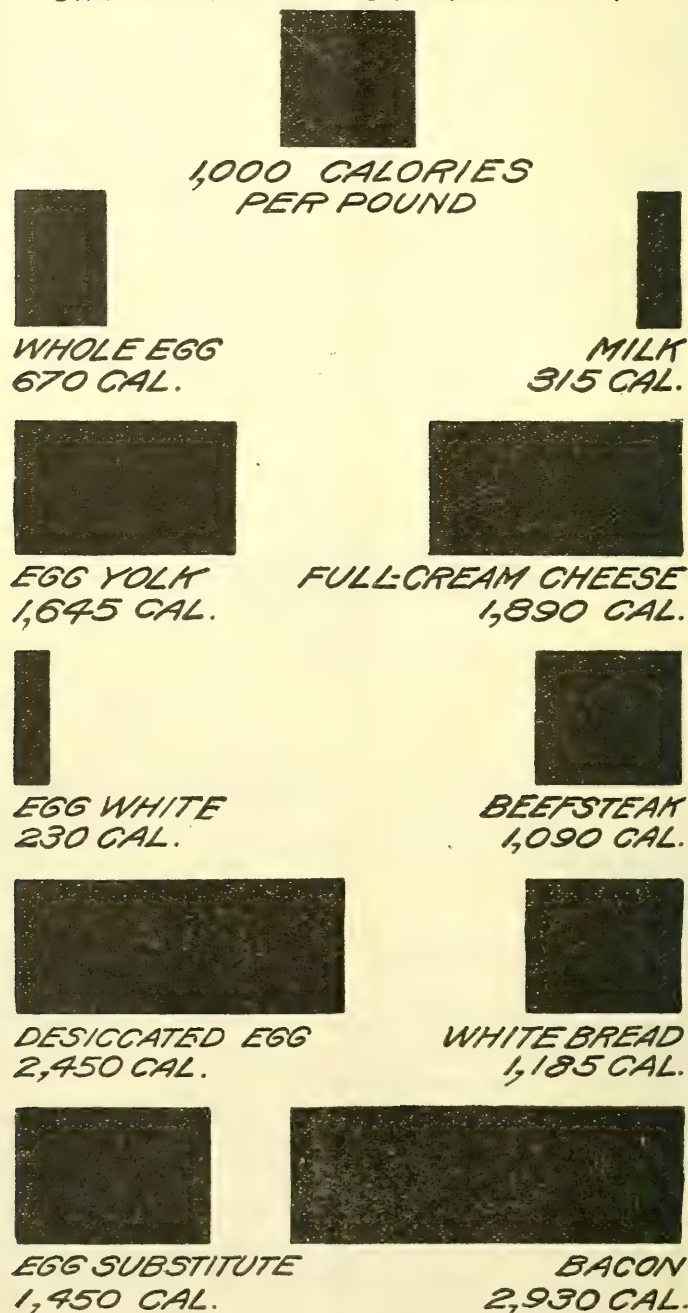


FIG. 3.—Energy value of eggs as compared with that of some other common foods.

of egg white was found to consist of four bodies—ovalbumen, conalbumen, ovomucin, and ovomucoid. The ovalbumen is the chief constituent and makes up the greater part of the egg white. The conalbumen has much the same chemical properties as ovalbumen. Ovomucin and ovomucoid are glycoproteids, and are present in small amounts.

Egg yolk contains a number of different bodies, including about 15 per cent vitellin (a protein); 20 per cent palmitin, stearin, and olein (in the fat); and 0.5 per cent coloring matter (see p. 4), besides some nuclein, etc., lecithin (a fat-like body containing phosphorus and now regarded as one of the very important food constituents, as it furnishes the body with phosphorus in a form in which it may be readily assimilated), and vitamins (see p. 7). Besides phosphorus, equivalent to a little over 1 per cent of phosphoric acid, the yolk contains such mineral elements as iron, calcium, and magnesium.

Since in all cases the egg is designed to furnish the sole source of material for growth and development of the young individual for a considerable time, it is evident that it must contain all the elements required; that is, it must be a complete food for the purpose intended, and this goes far to explain why it is such a valuable food for man. Milk is another familiar example of animal food containing all the elements of a complete food for the young and growing individual, and milk and eggs are frequently, though inaccurately, spoken of as perfect foods on this account and have always been considered especially important in the diet of invalids and children. It is true that they contain all the required elements for the growth and maintenance of the young mammal or the young bird, as the case may be, but this is not the sole test, for the elements are not in the right proportion for the sole nourishment of an adult individual. Man seems instinctively to have recognized this, since he uses eggs, as he does milk, in combination with other foods.

Though rich in iron and calcium, eggs contain an excess of nitrogen, phosphorus, and sulphur, and are, therefore, a predominantly acid food; that is, in the process of digestion an excess of acid end products is formed which the well-being of the body requires should be neutralized with basic substances, best supplied by such foods as fruits, vegetables, etc. The nitrogenous material in eggs, as in milk, is readily assimilated. It is especially noticeable that neither milk nor eggs contain purins, substances which are convertible into uric acid. In general, the iron, phosphorus, calcium, easily digested protein, and fat in eggs make them rank high in the list of foods in a well-selected dietary.

Many experiments have recently been reported concerning the presence in eggs of such substances as the so-called vitamins and the lipid-

like bodies which are thought to maintain the equilibrium of normal nutrition and to stimulate growth. As yet there is not unanimity of opinion as to the nature or the amount of these substances needed. It seems certain, however, that they are rather widely distributed and that a diet containing eggs, milk, fruits, and the other common foods in wholesome variety is likely to supply a sufficiency.

One of the constituents of egg albumin is sulphur, and the egg albumin is readily decomposed with the liberation of hydrogen sulphid. The bad odor of rotten eggs is due largely to the presence of this gas and phosphureted hydrogen, which is also formed. The shell of the egg is porous, and microorganisms which cause the egg to rot, or spoil, may gain access through the minute openings, and some of these in their growth cause the formation of these sulphur compounds. Even when a fresh egg is cooked, some sulphur is liberated, as is proved by the blackening of silver spoons or forks when they come in contact with boiled eggs. It is a matter of common observation that when eggs are boiled the yolk where it joins the white often has a more or less greenish color. Rubner has found that this discoloration is due to the action of the hydrogen sulphid produced by boiling on the iron of the vitellin of the egg yolk in the presence of alkali (formed when the white comes in contact with the yolk).

In the table no figures are given for the composition of the egg-shell, which, of course, is not used as food, though in times past it has had some use in domestic medicine. The shells of hens' eggs are made up very largely of mineral matter, containing 93.7 per cent calcium carbonate, 1.3 per cent magnesium carbonate, 0.8 per cent calcium phosphate, and 4.2 per cent organic matter. The shells of goose eggs, on an average, have the following percentage composition: Calcium carbonate, 95.3; magnesium carbonate, 0.7; calcium phosphate, 0.5; and organic matter, 3.5. The shells of ducks' eggs contain 94.4 per cent calcium carbonate, 0.5 per cent magnesium carbonate, 0.8 per cent calcium phosphate, and 4.3 per cent organic matter. The shells of other eggs are doubtless of much the same composition.

COOKING AND SERVING EGGS.

Methods of serving eggs, alone or in combination with other food materials, are very numerous. Those in which eggs are cooked alone—for instance, boiling, frying, shirring, and poaching—are, in general, simpler than those in which they are combined with other materials.

As regards the uses of eggs in cookery, they serve to improve the flavor, color, and texture of such foods as cakes, while in such dishes as custards and creams they also serve to thicken the material and to give it the desired consistency.

When beaten or whipped, eggs, and particularly egg whites, inclose air bubbles, many more being inclosed by fresh eggs than by packed or old eggs. When such beaten yolks and whites are added to batters or doughs the air bubbles are distributed throughout the mass, and when the dough is cooked the inclosed air expands and the walls of the air bubbles become firm, with the result that the porous structure is retained. Sponge cake and angel cake are familiar examples of foods made light with eggs. It is interesting to note that recipes for cakes and similar dishes to-day commonly call for fewer eggs than those of a generation or two ago. The reason is that, owing to the quite general use of baking powder, the house-keeper is not so often compelled to depend upon eggs to make her cakes light and need use only enough to give the desired flavor, color, and texture. In considering the uses of eggs as an ingredient of cakes and other dishes, it should be noted that they add materially to the nutritive value of the dish as well as to its quality and appearance.

Besides their uses in foods of various sorts, eggs are often employed as a garnish. Hard-boiled eggs, for instance, cut into different shapes, are a common garnish for cooked greens or for salad; or, instead of being cut or chopped, the yolk may be put separately through a ricer.

White of egg is employed for icings, meringues, and confectionery, particularly various sorts of cream candy, and for clarifying liquids (see p. 14).

Since eggs are especially rich in protein, combining them with flour, starch, and sugar (typical carbohydrate-yielding foods) and butter and cream, which are rich in fat, is perhaps an unconscious effort to prepare a food which shall more nearly meet the requirements of the body than any one of the ingredients alone. When eggs, meat, fish, cheese, or similar foods rich in protein are eaten, such other foods as bread, butter, potatoes, etc., are usually served at the same time, the object being, even if the fact is not realized, to combine the different classes of nutrients into a suitable diet. The wisdom of such combination, as well as of other generally accepted food habits, was proved long ago by practical experience. The reason has been more slowly learned.

The total number of methods of serving and preparing eggs is very large, but in nearly every case each is only a more or less elaborate modification of one of a few simple ways of cooking. Thus, an egg in the shell is cooked by immersion in hot or boiling water or is less commonly roasted. An egg removed from the shell may be cooked in hot water or in hot fat. In the latter case it may or may not be beaten or stirred. Combined with other materials to form

various made dishes, eggs are boiled, baked, steamed, or fried, as the case may be.

Changes in weight are often noted when foods are prepared for the table. These vary with the kind of material and the method of preparation, but, in general, loss in weight is due to volatilization, and gain to the absorption of water. Much careful experimenting with eggs cooked in the shell shows that if the egg remains in water a few minutes it loses only a very little material, probably water, which passes out through the porous shell. If it is left in the water for a longer time it may gain weight by absorbing water. In either case the change is too small to modify the food value of the egg appreciably.

Different methods of cooking cause marked changes in the appearance and structure of eggs. Thus, boiled eggs—that is, eggs cooked in the shell in hot, though not necessarily boiling, water—vary greatly in hardness, according to the length of time the cooking is continued, the method of procedure, etc. The directions commonly given for preparing soft-cooked, medium-cooked, and hard-cooked eggs vary. Any of them without doubt will give the desired result if sufficient care is exercised. The chief difficulty is in securing uniform results, especially with soft-cooked or medium-cooked eggs. It must be remembered that such results can not be expected when conditions vary. The time of cooking, the quantity of water used, the number, size, freshness, and temperature of the eggs, and the kind of vessel used are important factors. Thus, eggs which have been kept in an ice chest require more heat to warm them before cooking begins than do those which have been kept at room temperature. Again, so apparently trivial a detail as the sort of vessel used (whether earthen or metal), or the place where the vessel stands during cooking, may produce different results. Even after the eggs are taken out of the water they may continue to cook, and the length of time they stand before using may make a noticeable difference in their consistency. Many persons prefer to have eggs cooked at the table in a chafing dish or other suitable vessel. In such cases the conditions may be controlled with comparative ease, and uniform results obtained with a little practice and care.

As previously stated, egg white, when heated at the temperature of boiling water for a considerable time, becomes hard and contracts. This explains the curdling of custards and the shrinkage and toughening of omelets, soufflés, meringues, sponge cake, and similar mixtures. The firm coagulation of albumin at 212° F. explains the use of egg white for clarifying coffee, soup, or other liquids. The albumin, which is mixed with the liquid before boiling, coagulates and incloses the floating particles, leaving the liquid clear. When eggs are removed from the shell, a little of the white usually clings to the inner surface unless it is scraped. Such eggshells are often used for clarify-

ing purposes instead of the whole egg (see p. 13). The clarifying properties are, of course, due to the egg white and not to the shell.

Eggs are also employed in the arts, for instance, the use of egg white in the manufacture of albumin paper and of egg-yolk oil in finishing leather.

DIGESTIBILITY OF EGGS.

Eggs are commonly said to be very digestible, especially when raw or slightly cooked. Probably most persons would understand by this that they digest without giving rise to pain or other physical discomfort. This is undoubtedly true, but the word "digestible" has another meaning in most discussions of food values. It refers not only to the ease, but also to the thoroughness, of digestion—that is, to the total amount of material that the food gives up to the body in its passage through the digestive tract. The original nature and condition of a food, the method of cooking, and the quantity eaten at a given time are among the factors that determine the amount of any given material that can be digested, but, in general, it is fair to say that the variations are less than is commonly supposed, the quantity of undigested food excreted from the body being usually very small.

Statements often far from accurate are frequently made with regard to the length of time required to digest different foods. Some of them are based on investigations (some old and some recent) which take into account chiefly the length of time food remains in the stomach, assuming that this represents digestion and forgetting that digestion in the intestines must also be considered. Other statements are based on artificial digestion experiments in which the food is subjected in the laboratory to the action of digestive ferments which occur in the body. It is probable, however, that all the conditions of digestibility in the body can not be reproduced in the laboratory, and, although the results obtained are interesting and often valuable, it is worthy of note that careful investigators are much slower to make sweeping deductions from them than are popular writers on the subject.

As regards thoroughness of digestion, that is, the proportion of nutritive material the body retains from a given food, eggs rank high, reliable experiments having shown that, on an average, 97 per cent of the protein and 95 per cent of the fat are assimilated.

The question as to whether eggs are more or less digestible raw, slightly cooked, or hard cooked has also been studied by a number of investigators, the results indicating that, while cooking makes some difference with the rate (as shown by test-tube work), it makes little with the thoroughness of digestion. Even as regards quickness of digestion there is little difference between raw and slightly cooked

eggs. In the case of hard-boiled eggs the yolks are probably as digestible as those of less thoroughly cooked eggs. However, the whites are so firm in texture that, unless they are finely chopped or thoroughly masticated, the digestive juices will not be able to permeate them quickly, and so portions may escape digestion or remain in the digestive tract for several days and decompose. This explains why hard-boiled eggs are often excluded from the diet of little children and invalids and suggests that even healthy adults should be careful to masticate them thoroughly.

From all the evidence it seems fair to conclude that eggs are very thoroughly digested and that the length of time of cooking has less effect upon this factor than upon the time required for digestion in the stomach. In a healthy man the latter consideration is probably not a matter of much importance, as digestion will continue in the intestine. In the diet of invalids it may be more important. However, diet in such cases is a matter for the attention of skilled physicians, and one should be guided by their advice.

Apparently there is no reason for believing that ordinary breakfast beverages (tea, coffee, or cocoa) have any marked effect upon the thoroughness of digestion of eggs, notwithstanding the popular statement sometimes made to this effect.

WHOLESOMENESS OF EGGS.

Eggs are wholesome as well as useful and nutritious food. Over-indulgence may lead to digestive disturbance, as it may with any food, but, on the whole, eggs can be eaten by most people in usual quantities without such results. Occasionally, however, a person is found who is habitually made ill by eating eggs, just as there are those who can not eat strawberries or other foods without distress. Such cases are due to some personal idiosyncrasy, showing that in reality "one man's meat is another man's poison." The physiological explanation for them is probably that these persons have become abnormally sensitized to a specific protein body in the egg which will then act as a poison when digested and taken into the circulation.

Under certain conditions eggs, like other foods, may be accidental carriers of disease by conveying to the body harmful bacteria or parasites. It is possible for an egg to become infected with microorganisms, either before it is laid or more especially after it is laid, since the porous shell offers no great resistance to microorganisms, including those which cause it to spoil or rot. If an egg is eaten raw or only slightly cooked, microorganisms, if present, can be communicated to man and may cause disease if they are of the sort to do so. If an egg remains in a dirty nest, for example, defiled with the microorganisms which cause typhoid fever, carried there on the hen's feet or feathers, it is not strange if some of these bacteria occasionally

penetrate the shell and the egg thus becomes a possible source of infection. Perhaps one of the most common troubles due to bacterial infection of eggs is the more or less serious illness sometimes caused by eating those that are stale. This, often called ptomaine poisoning, is more correctly styled food poisoning, and is caused by microorganisms that are commonly associated with filth.

Judged by the comparatively small number of cases of infection or poisoning due to eggs, reported in medical literature, the danger of disease from this source is not very great. However, in view of its possibility, it is best to keep eggs as clean as possible and thus endeavor to prevent infection. Clean poultry houses, poultry runs, and nests are important, and eggs should always be stored and marketed under sanitary conditions. The subject of handling food in a cleanly manner is too seldom thought of, and what is said of eggs in this connection applies to many other foods with even more force. Since it is not wise to wash eggs that are to be kept, only clean ones should be selected for this purpose. Always, when eggs are used, the shells should be carefully cleaned just before they are broken, as otherwise any dirt present on the outside may find its way into the food.

Occasionally the eggs of worms, etc., have been found inside hens' eggs, as indeed have grains, seeds, etc. Such bodies were doubtless accidentally occluded while the white and shell were being added to the yolk in the egg gland of the fowl. This is a rare occurrence and has little to do with the general question of the wholesomeness of the egg. If it should occur the egg should not be used. The bloody spot often found in eggs shows that growth of the embryo has proceeded too far for the egg to be considered of desirable quality.

In general, if one actually has an idiosyncrasy toward eggs one should avoid them. Others should do all they can to secure clean, good eggs, and may then rest assured that these are likely to prove wholesome.

THE SUPPLY OF EGGS FROM THE HOUSEKEEPER'S STANDPOINT.

In order to purchase eggs to the best advantage the housekeeper should be familiar with the source of supply. A generation or so ago each locality depended upon its own farms for eggs, but with the growth of cities and the resulting increased demand this state of things has changed. The eggs raised in the Atlantic and Pacific States are still mainly consumed in or near the place of production, but they are not sufficient to supply these regions, and it is necessary to ship into these regions large quantities of eggs from several of the States of the Mississippi Basin, which produce many more eggs than can be used there. Refrigerator cars, cold-storage warehouses, and special cases devised to prevent breakage make it possible to ship

eggs long distances and keep them for fairly long periods in good condition.

When the housewife depends upon eggs from her own hens, or even when she or the grocer buys direct from a local producer, she can expect to get eggs less than a week old, and the term "fresh-laid eggs" has some meaning. When, however, she buys them in city markets, especially during the autumn and winter months when hens are not laying freely, the chances are that all except a very few high-priced eggs purchased from some local producer were laid at least several weeks before and very likely hundreds of miles away. This does not mean that city-market eggs are necessarily bad eggs. On the contrary, when handled by good methods, they may be better in quality than fresh local eggs that have been improperly cared for.

The housekeeper's problem in selecting eggs is complicated by the fact that it is hard to tell the quality of an egg from its appearance. There is undoubtedly a quality in the absolutely fresh, clean egg which is not found in any other and which will last only a day or two under the best of conditions and can not always be secured even in new-laid eggs. This change or loss of quality depends quite as much on the character and cleanliness of the egg and the conditions under which it is held as on the length of time it is kept. Since examination is now almost a necessity in the trade, and the importance of reliable standards of excellence is being recognized the housekeeper should be familiar with the commercial methods.

The main points by which an expert judges the quality of an egg are size, shape, soundness and cleanliness of the shell, and appearance of the interior when candled (held against an opening which permits light to shine through the egg). When an egg is newly laid, its contents seem to fill the shell, as it is seen against the candle, but very soon an air space begins to appear in one end and gradually increases in size until it may fill even half the shell. This shrinking is due to the evaporation of water through the porous shell, and as it increases the weight of the egg decreases. Hence, the old household floating test for eggs—fresh ones sink when put into a pail of water, while old ones float. When a fresh egg is candled the yolk is barely distinguishable from the white, save as a slightly darker area in the center of the egg. In older eggs the yolk looks darker and often shifts its place in the egg. Various kinds of dark spots and blotches may also develop, due to different causes, but all indicating a spoiling egg. When all of the egg meat looks dark in candling the egg is rotten. The art of candling is easily learned and often practiced by housekeepers.

The housekeeper can buy more intelligently if she knows how eggs are graded in the trade and that prices vary accordingly. The grades are commonly designated: "First quality"—large, fresh eggs with

clean, uncracked shells, free from spots or blotches in candling and weighing at least a pound and a half per dozen; "second quality"—eggs which would rank as first except that they either are undersized or have begun to shrink, or eggs in which chick development is just beginning, but has not reached the stage when a blood ring appears. "Dirties" are what the name implies and are always sold at low prices, even when large and fresh. "Checks" are eggs with cracked shells; when the cracks are large enough to let the contents escape, they are called "leakers"; when the cracks are too slight for this they are called "blind." Both of these grades may be sold as food, but they do not keep properly, and they bring low prices. "Spots" and "rots" of various kinds are rarely sold in the shell at retail for table or cooking use, though it is said that large quantities find their way into cheap bakeshop and cheap restaurant dishes, and have at times been used by unscrupulous manufacturers in the preparation of frozen and desiccated products. Many such eggs are used also in tanning leather and for other technical purposes.

The spoiling of eggs is due to two sets of causes, first, the germination of fertile eggs and development of the chick, which is a natural process; and, second, the decomposition by molds or bacteria due to accidental causes. Considering the eggs she keeps on hand at home, as well as those she buys, the housekeeper should realize that each is likely to occur if proper handling and care are lacking and that both are preventable. The surest method of preventing losses due to the development of the embryo is the production of infertile eggs. Mating is, of course, essential to the development of the chick, but if the cocks are separated from the hens as soon as the hatching season ends in the early summer, a large percentage of the loss from bad eggs may be avoided. This is as well worth attention when eggs are home produced as it is in professional poultry raising.

Too much warmth favors both incubation and decomposition, especially in the case of newly-laid eggs. Eggs should be collected promptly and kept in a cool place, especially during hot weather, for heat is just as harmful during the first few days after eggs are laid as it is later, and no amount of care in pantry and refrigerator or in packing rooms, refrigerator cars, and warehouses can give back the good quality to eggs that have lain for several days in a hot nest, been kept in a warm pantry, or been exposed to the hot sun on their way to town.

The loss of quality, due to molds and bacteria in the egg is brought about by their growth and by the chemical compounds, formed by them, which give spoiled eggs their peculiar appearance, taste, and odor. Some of the microorganisms produce a musty taste, and others produce compounds of sulphur and the characteristic odor of rotten eggs. As has already been pointed out (p. 16), some of these

molds and bacteria are not injurious to health, while others may give rise to more or less serious illness. The best way to prevent the infection of eggs by molds and bacteria is to produce infertile eggs and to keep them clean and dry from the time they are laid until they are finally used. The coating of mucilaginous material on the outside of the egg and the very thin membrane, or "skin," on the inside protect the egg from the invasion of molds and bacteria. The shell coating is easily removed by water or by rubbing. Also as eggs grow old the natural protection of the egg becomes less effective. Therefore, deterioration due to molds and bacteria is more likely to occur if the egg is washed or the shell becomes moist by being kept in a damp place. If eggs are dirty enough to wash it is better to do so and use them at once than to "put them down." Neglected and stolen nests (usually dirty and so sources of bacteria, etc.) are probably the chief cause of molded or rotten eggs, and so hens should always have clean, airy nests. Housekeepers who are careful will not choose dirty eggs. If for any reason they must be used they should be carefully washed and wiped.

These causes of spoiling are important matters for the housekeeper, since they have a bearing on supply and market price. It is to the housekeeper's interest to have only eggs produced under good conditions brought to market, because this means less loss in handling and an increased supply of good eggs, which in turn, affects prices favorably.

As a means of securing a supply of fresh eggs for table purposes, the purchase of eggs direct from the producer by parcel post is worth consideration by the housekeeper.

Since eggs vary more or less in size and weight, though very little in composition (see p. 6), it follows that they vary in the amount of food material which they supply. For this reason housekeepers who have a choice very commonly like to select large eggs. That size has an effect on the cost of eggs when they are purchased for a uniform price per dozen is evident when one considers that a dozen pullets' eggs, weighing 18 ounces, at 25 cents per dozen, supplies eggs at 22.9 cents per pound, while hens' eggs, weighing 24 ounces at the same price per pound would supply eggs at 16 $\frac{2}{3}$ cents per pound. Such differences are especially worth considering when eggs are used in quantity. There are few exact household standards for cookery, and using eggs as they come, by number rather than by weight, would probably not imply important variations. However, it is well known that when a recipe calls for 4 eggs one may use instead of 4 of average size either 3 large or 5 small ones.

For reasons of economy as well as accuracy in cookery there is a growing tendency to use eggs by weight or measure instead of by

number. Obviously, such a plan is actually, though not relatively, more economical when large recipes are used, as in boarding houses, hotels, or public institutions, than it is in a home where the family is small.

PRESERVING EGGS AND ITS EFFECT ON THE HOUSEHOLD SUPPLY.

Preserving eggs in one way or another seems to be almost universal and to have been practiced for a very long time, and presumably, like many other everyday things, owes its origin to the observation and experience of generations. The object usually sought is to keep eggs as nearly as possible as they are when new laid. It is not without interest to note that in some regions, notably the Orient, ripening is sought as well as preservation. To insure this the eggs are buried or coated with earth, brick dust, clay, or some other substance, and kept for weeks or months, when they undergo a fermentation or ripening and acquire such a texture and flavor that they are often compared with "ripe" cheese. Egg preservation such as we are familiar with is the opposite of this and attempts not only to prevent such ripening processes, as well as putrefactive changes, but also to hinder or prevent any bacterial or other changes which lessen original quality.

The whole matter of preserving eggs is of importance to the teacher of home economics and the housekeeper, for not only does the housewife preserve eggs for her own use, but the available supply of those she purchases and their cost are directly influenced by such factors.

As regards home storage, housekeepers under most circumstances must keep eggs on hand for short periods for present use, and frequently preserve them when the supply is abundant for use later when fresh eggs are less plentiful. Eggs for present use, that is, those stored for a short time only, should be kept where it is cool and moderately dry—in a refrigerator, for instance, a dry cellar or some similar place. Since they will absorb odors they should be kept away from strong-smelling substances. With such precautions eggs fresh at the start will keep in good condition for use in cookery, as most housekeepers know, for at least two or three weeks. If infertile, they keep longer and in better condition. When one wishes to keep them for a still longer period there are methods of preserving them which can be followed at home with good results.

In general household methods of preserving eggs depend upon the fact that when the pores of the shell are closed, decay is hindered. The reason is that this prevents the entrance of molds and bacteria and hinders the growth of any that may be already present. Among methods often used with more or less success to stop the pores are

burying eggs in oats, bran, or salt; rubbing them with butter; dipping them in melted paraffin; covering them with varnish or shellac; or putting them down in limewater or in a solution of water glass.

As the result of many trials in farm and other homes, as well as at the experiment stations, it is generally agreed that putting down eggs in a solution of water glass or in limewater gives more satisfactory results under home conditions than the other methods mentioned.

Water glass is a popular name for both potassium and sodium silicate. The commercial article (often a mixture of the two) is cheaper and should be used rather than the "chemically pure" water glass for preserving eggs. It is commonly sold as a siruplike liquid, sometimes as low as 1.75 cents per pound in carboy lots, the retail price being perhaps 10 cents per pound on an average.

A solution of the desired strength for preserving eggs may be made by dissolving 1 part of the siruplike water glass in 10 parts by measure of pure water, preferably water which has been boiled to make sure that it is free from mold spores, bacteria, etc. A gallon of the water glass will make solution enough to cover 50 dozen eggs if they are carefully packed.

The eggs should be as fresh as possible (if infertile, so much the better), and packed in a crock, keg, or barrel thoroughly washed and scalded just before its use. Sufficient solution should be poured over the eggs to cover them well. They should be stored in a cool place, not only to prevent the growth of any microorganisms which may have been present before the water glass sealed the pores of the eggshells, but also because water glass will occasionally deposit in patches on the shells if the room is warm.

Many teachers of home economics and housekeepers have asked whether or not water-glass solution can be used a second time. Occasionally this might answer, but since it is far from certain it is not desirable nor worth the risk.

The shells of eggs put down in water glass sometimes crack in boiling, but this can be prevented by sticking a pin through the shell into the air space at the blunt end of the egg before it is boiled.

Limewater, which some consider as satisfactory for preserving eggs, is slightly less expensive than water glass. A solution is made by placing 2 or 3 pounds of unslacked lime in 5 gallons of water and allowing the mixture to stand until the lime settles and the liquid is clear. The eggs should be placed in a clean earthenware jar or other suitable vessel, and covered with the clear limewater. Sometimes a pound of salt is used with the lime, but many persons believe that when this is done the eggs have a slight taste of lime.

Eggs preserved in water-glass solution or in limewater answer admirably most purposes for cookery. Some do not consider them

entirely satisfactory for table purposes, while others do not object to them. Naturally they are used most acceptably in an omelet seasoned with onion, tomato, or chopped green pepper, or in some other form in which seasoning can be used to cover the taste of the egg.

Though many housekeepers can depend upon fresh eggs and eggs stored at home, a larger number must depend upon those which they purchase, and this almost invariably means a dependence for some part of the time upon eggs commercially stored.

Commercial preservation of eggs, which is largely preserving by cold storage, is an industry which has developed very greatly in recent years. The success of cold storage depends upon the fact that low temperature is unfavorable to spoiling; that is, to putrefactive changes, growth of molds, etc., brought about by microorganisms. The development of methods of artificial refrigeration have made possible the use of low temperature for this purpose.

In order that advantage may be taken of favorable climatic conditions, eggs are commonly purchased for storage as early in the year as they are abundant, rather than in the hot months. Since the infertile eggs keep better than fertile ones, they are given the preference for cold storage. It is obvious that the better the egg when it goes into storage the better its quality when used. Within the usual limits of storage, perhaps from six to nine months, eggs do not deteriorate much, and it is not the case, as many teachers of home economics and housekeepers believe, that the shorter the time of storage the better the quality. First-quality storage eggs, on the whole, compare favorably with any except the better grades of fresh eggs, and are certainly more desirable than late summer or early autumn eggs held over by the producer in the hope of securing better prices. As regards their use in the home, cold-storage eggs of good quality are very satisfactory for cookery, and, indeed, many persons find them satisfactory for table use, though those who are very particular about such matters will no doubt always prefer a new-laid egg.

In considering the whole question the housekeeper and the student of home problems should realize that the fact that storage tends to equalize the market and that in many cases one would have difficulty in procuring eggs at all if one could not depend upon those which have been stored.

These matters have been considered here from the standpoint of the home supply and the use of eggs in the home. Those who wish information regarding the production, marketing, or storage of eggs should consult the publications of the Animal Husbandry Division, Bureau of Animal Industry, and of the Bureau of Chemistry.

Whatever her supply, whether fresh eggs, eggs preserved at home, or cold-storage eggs, the housekeeper who wishes to economize should

realize that she should use eggs most freely when they are most abundant and cheapest. When they are high in price she will either give preference to recipes which call for fewer eggs or she will choose dishes which do not require eggs, and to keep up the nutritive value of the diet will depend more upon milk, cheese, meat, and other things which are similar to eggs in respect to the food materials they supply.

FROZEN EGGS, DESICCATED EGGS, AND EGG SUBSTITUTES.

Though eggs, like other animal foods, will keep for a long time when frozen, housekeepers rarely resort to this method of preserving them. It sometimes happens, however, that eggs freeze accidentally. When this is the case they should be thawed slowly (which may be easily accomplished by putting them into cold water and allowing them to stand a sufficient time in a cool place) and used at once.

Commercial frozen eggs—that is, eggs broken and frozen in large containers, with whites and yolks either separate or mixed—are a common product and have found considerable popularity in bakeries and restaurants, where eggs are used in quantity. Obviously, the quality of the product depends upon the grade of the eggs frozen as well as upon the method of handling.

Preserving foods by drying them is a method which is common and often very satisfactory. Many housekeepers find it convenient now and then to dry a few egg whites for use in settling coffee or for some similar purpose. This can be done by spreading the white in a thin layer on a platter or other suitable dish and drying it at a gentle heat in the oven or in the sun.

Several different methods are employed commercially in the preparation of egg powders or desiccated eggs true to name. The whole egg may be dried, or the white, or the yolk. The process varies somewhat, the product being sometimes flaky and sometimes a fine, smooth powder. In general, 90 per cent of the water originally present is removed.

As regards composition, desiccated eggs (see table, p. 6) closely resemble eggs from which the bulk of the water has been removed. Since fresh eggs contain about 75 per cent of water, it would take about 4 pounds to make 1 pound of dry egg. In general, desiccated eggs are readily prepared for use by mixing with a small quantity of water, and practical tests have shown that they give fairly good results when used in cookery. It is also possible to use them, thoroughly mixed with a small quantity of water, for omelets, etc. According to observation, desiccated eggs keep well and are wholesome if well made and handled. Like frozen eggs, they have much the same food value as fresh eggs. At present they are used chiefly by bakers, being generally cheaper than fresh eggs, particularly in

a time of scarcity. They are of interest to the housekeeper as she may find them at times very convenient or economical—for instance, for use on a family camping trip.

As previously stated, eggs are used in cookery for their effects upon consistency and quality of foods as well as for their food value. As many housekeepers know it is possible, when eggs are lacking, to use other foods which will give something the same appearance as eggs; for instance, flour or starch may be used to thicken custards or gelatin used in making an icing or a pudding. The dish may be acceptable, but it goes without saying that the food value would not be the same as if eggs were used.

There are a number of commercial products designed as egg substitutes, some of which approach eggs in composition much more nearly than others. Of these products some are fairly well known to housekeepers, while some are used chiefly in commercial baking and for similar purposes. The various kinds differ much in composition, some being much more like eggs in protein content and energy value than others. In judging such products one should not rely upon appearance, for yellow color does not necessarily indicate other egg yolk characteristics. Some of these egg substitutes, at least, are manufactured from skim milk and are said to contain milk casein and albumin mixed with a little flour. Such a product is evidently rich in protein. Other egg substitutes have been devised which consist of mixtures of animal or vegetable fats, albumin, and starch or flour.

Goods have also been marketed for use as egg substitutes which contain little or no albumin, but which are apparently made up quite largely of starch, colored more or less with some yellow substance. They are commonly advertised for making custards and puddings similar in appearance to those in which fresh eggs are used. If the housekeeper wishes to use them she should not overlook the fact that in the diet they can not replace fresh eggs, since they do not contain the same kind or quantity of nitrogenous matter or fat. This may be an important matter, particularly if such an egg substitute is used in the diet of invalids or children in the belief that it contains the same nutrients as eggs.

IMPORTANCE OF EGGS AS FOOD AND THEIR PLACE IN THE DIET.

That eggs are of great importance in the list of foodstuffs is shown by the last census report, which gives the number produced on farms in 1909 as 1,457,000,000 dozen, or 16 dozen per capita. Their total value was estimated at \$306,688,960. If the eggs produced elsewhere than on farms were included this value would be considerably increased. The value per dozen ranged from 15.9 cents to 27.5 cents, with 19.3 cents as the average, and was greatest near large cities,

in mining districts, and in such sections as Alaska and Hawaii, where the egg production was very small as compared with the population and most of the eggs were shipped from a great distance.

The growing importance of eggs is also shown by the growth of the industry. The United States formerly imported a large number of eggs and exported very few. The ratio has changed within recent years, and now the exports largely exceed the imports as the following figures indicate. In 1890 the total number of eggs exported was 381,000 dozen, worth \$59,000. In the 12 months ended June, 1915, it was 20,784,424 dozen, worth \$5,003,764. In 1890 this country imported 15,000,000 dozen eggs, which were valued at \$2,000,000, and in 1915 only about 3,046,631 dozen, valued at about \$438,760.

Eggs are used in nearly every household almost every day in one form or another and in varying amounts. From the results of numerous dietary studies it has appeared that on an average eggs furnish 3 per cent of the total food, 5.9 per cent of the total protein, and 4.3 per cent of the total fat used per man per day. For comparison it may be noted that cheese furnishes 0.4 per cent of the total food, 1.6 per cent of the total protein, and 1.6 per cent of the total fat, while milk and cream together furnish 19.9 per cent of the total food, 10.5 per cent of the total protein, and 10.7 per cent of the total fat, in addition to some carbohydrates (which eggs and cheese do not supply in appreciable quantities), and veal and beef together were found to furnish 10.3 per cent of the total food, 24.6 per cent of the total protein, and 19.5 per cent of the total fat.

The amount of nutritive material which a given quantity of eggs will furnish at any stated price per dozen may be readily calculated. When eggs are 25 cents per dozen, 10 cents expended for them will furnish 0.60 pound of total food material containing 0.08 pound of protein and 0.05 pound of fat, the whole having a fuel value of 380 calories. At 35 cents per dozen, 10 cents will procure 0.43 pound of total food material, containing 0.06 pound of protein and 0.04 pound of fat, and furnish 275 calories of energy. At 45 cents per dozen, 10 cents' worth of eggs will furnish 0.33 pound of total food material, supplying 0.04 pound of protein, 0.03 pound of fat, and 210 calories. Ten cents expended for beef at 16 cents per pound will furnish 0.63 pound of total food material, containing 0.12 pound of protein and 0.08 pound of fat and supplying 560 calories. Expended for beef sirloin at 30 cents per pound, 10 cents will furnish 0.33 pound of total food material, containing 0.05 pound of protein and 0.06 pound of fat and supplying 345 calories. If wheat bread is purchased at 5 cents per pound, 10 cents will pay for 2 pounds of total food material, containing 0.18 pound of protein, 0.03 pound of fat, and 1.06 pounds of carbohydrates, and yielding 2,430 calories.

The relative economy of different kinds of food often depends on more than the amount of nutrients which can be purchased for a given sum. This is especially true in the case of eggs, which not only give variety to the diet and furnish an easily digested, nutritious food, especially suitable for breakfast or other light meal (an important item for those of sedentary habits), but also are almost indispensable in many kinds of cooking. It should never be forgotten that when eggs are used in making fancy breads, cakes, desserts, etc., they not only improve the appearance, texture, and flavor of the dish, but also increase its nutritive value.

Many families of moderate means make a practice of buying fresh meat for but one meal a day—that is, dinner—using for breakfast either bacon, dried beef, codfish, or left-over meats, etc., and for lunch or supper bread and butter and the cold meat and other foods remaining from the other two meals, with perhaps the addition of cake and fresh or preserved fruit. It is the thrifty housekeeper, who uses all her material as economically as possible in some such way, who is likely to fall into the error of excluding eggs at higher prices almost entirely from her food supply. If her economy were directed principally to restricting the use of eggs in the making of rich dessert dishes, cake, and pastry, one might not only refrain from criticizing, but welcome the circumstances which necessitated the making of simpler and therefore more wholesome desserts, but usually the housekeeper economizes on eggs by the more obvious method of omitting to serve them as a meat substitute.

The statement so frequently made by housekeepers that eggs at a relatively high price are cheaper than meat at a relatively low price is true in one sense, not, of course, with reference to the total amount of nutrients obtained for the money expended, but because a smaller amount of money is needed to furnish the meal. That is to say, whereas 1.25 pounds of beefsteak, costing 40 cents, at 32 cents per pound, would barely suffice to serve five adults, in many families five eggs, costing 17 cents, at 40 cents per dozen, would serve the same number and probably satisfy them equally well. If the appetites of the family are such as to demand two eggs per person, doubling the cost, they still cost less than the steak at the assumed prices. Many persons eat more than two eggs at a meal, but the average number served per person, it is believed, does not generally exceed two in most families, and experience has shown that very commonly orders in a hotel restaurant are for one egg. Frequently when omelets, soufflés, creamed eggs, and other similar dishes are served in place of meat or fried, poached, or boiled eggs, less than one egg per person is used.

These statements must not be understood as advocating a free use of eggs at any price, but merely as pointing out that even at the higher prices the occasional use of eggs in place of meat need not be regarded as a luxury. This is illustrated by observations made by Miss Isabel Bevier and Miss M. E. Sprague¹ during a dietary study of some 115 women, most of them college students. It was found that the amount of certain foods required for a single meal, when any one of them was served, was: Beefsteak, 36 pounds; mutton chops, 45 pounds; hamburg steak, 24 pounds; sausage, 30 pounds; bacon, 12 pounds; dried beef, 4 pounds; and eggs, 15 pounds, or 10 dozen.

At the price at which board was furnished, steaks and chops were too expensive for use as breakfast dishes. At the time the study was made bacon and dried beef were both considered cheap. Hamburg steak and sausage were regarded as practicable and were occasionally used, but eggs at 22 cents per dozen were thought expensive and at 25 cents per dozen so dear that they could not be used. Yet, as the study showed, at either price the quantity of eggs actually required to satisfy the members of the club cost less than the amount needed of any of the foods except bacon and dried beef. Furthermore, it was easier to utilize boiled eggs not consumed at table than the left-overs of meat. It appears, therefore, that in this case, as regards both economy and palatability, the use of eggs as a breakfast dish was warranted, and the problem discussed is one worth a housekeeper's attention.

The eggs, the steaks, and other materials used were not equivalent in nutritive value, but it must be remembered that other foods were served with the meat or eggs, and that the total amount of nutrients consumed at the meal need not have varied greatly from day to day, although the menu was quite different. Variety from meal to meal and from day to day is recognized as desirable in the daily diet, and this is another reason why such uses of eggs are worth considering.

It is generally recognized that eggs require less time and labor for cooking than most common foods, and for this reason their use as the hot dish at a meal may often be an economy. There are undoubtedly cases in which a small saving of gas or other fuel is of importance, but in many others it is less important than a saving of time or labor. Without question a reason for the popularity of eggs in most households is that they may be so easily and quickly prepared for the table in appetizing ways.

In the case of eggs, like other foods, the income and the need for economy must determine how far and in what ways they are to be used when they are high in price. Judged by their composition and digestibility, eggs are worthy of the high opinion in which they are

¹ U. S. Dept. Agr., Office Expt. Stas. Bul. 91 (1900), and unpublished data furnished by Miss Sprague.

usually held. Furthermore, they are generally relished. Although the physiological reasons were perhaps difficult to find, it was long ago conceded that the attractiveness and palatability of any food must not be forgotten in considering its true nutritive value. Refinement in matters of diet should keep pace with growth in general culture, and foods which please the esthetic sense as well as satisfy hunger are certainly to be preferred to those which serve the latter purpose only, if they can be obtained with the income at one's command.

**PUBLICATIONS BY THE U. S. DEPARTMENT OF AGRICULTURE OF
INTEREST IN CONNECTION WITH THIS BULLETIN.**

- Yearbook 1910, The effect of the present method of handling eggs on the industry and the product.
- Yearbook 1912, How the produce dealer may improve the quality of poultry and eggs.
- Yearbook 1914, Egg and poultry demonstration-car work in reducing our \$50,-000,000 waste in eggs.
- Farmers' Bul. 142, Principles of nutrition and nutritive value of food.
- Farmers' Bul. 445, Marketing eggs through the creamery.
- Farmers' Bul. 594, Shipping eggs by parcel post.
- Farmers' Bul. 656, The community egg circle.
- Department Bul. 51, A bacteriological and chemical study of commercial eggs in the producing districts of the Central West.
- Department Bul. 224, A study of the preparation of frozen and dried eggs in the producing section.
- Bur. Anim. Indus. Circ. 140, The egg trade of the United States.
- Bur. Anim. Indus. Bul. 141, The improvement of the farm egg.
- Bur. Anim. Indus. Bul. 160, The care of the farm eggs.
- Bur. Chem. Circ. 64, Studies of poultry from the farm to the consumer.
- Bur. Chem. Circ. 83, Deterioration of eggs as shown by changes in the moisture content.
- Bur. Chem. Circ. 98, Practical suggestions for the preparation of frozen and dried eggs.
- Bur. Chem. Circ. 104, A study of the enzymes of the egg of the common fowl.
- Bur. Chem. Bul. 115, A preliminary study of the effects of cold storage on eggs, quail, and chickens.
- Bur. Chem. Bul. 158, A bacteriological study of shell, frozen, and desiccated eggs.
- Bur. Statis. Bul. 93, Cold-storage business features.
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PROFESSIONAL PAPER

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IMPROVED APPARATUS FOR DETERMINING THE TEST WEIGHT OF GRAIN, WITH A STANDARD METHOD OF MAKING THE TEST.

By E. G. BOERNER, *Assistant in Grain Standardization.*

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INTRODUCTION.

The improved testing apparatus for obtaining the weight per bushel described in this bulletin was designed to reduce to a minimum the personal error in making the test and to standardize the method of determining the test weight of grain.

The importance of "weight per bushel" is well known to the grain trade. It is a recognized fact that, other things being equal, the heavier a sample of grain, the better it is; and consequently we find grain dealers, grain judges, and grain inspectors referring to and relying on this test almost more than on any other. The grain dealers know that a heavy, plump sample has the highest commercial value or will change hands most readily at a given price, and the miller knows that the heavy sample will produce the most flour.

Judges at shows and competitions, especially when the competition is close, often select the best samples from among the competing lots of grain and then award the prizes according to the weight per bushel.

Investigators endeavor, by comparing different varieties of grain tested during a series of years, to determine which varieties in a given district produce on the whole the heaviest grain, in order to

meet the two important requirements of high yield per acre and a high commercial grade when the grain gets into commerce.

In order to indicate the comparative values of different lots of grain, the grain-inspection departments of various States and grain exchanges have promulgated and adopted grain grades and rules in which the test weight is one of the principal factors.

When grain is sold by grade, as most of that which gets into commerce is at one time or another before it is finally consumed, the price is almost invariably found to be parallel with the grade; that is, the highest grades command the highest prices, while the lowest grades command the lowest prices.

In these grades a minimum test weight per bushel is usually specified for at least the higher grades of wheat, oats, barley, rye, flaxseed, and buckwheat.

These conditions illustrate the importance of the weight per bushel test for grain. Mere haphazard testing, however, is of little use and only leads to confusion and disputes among the interested parties. It is needless to state to one familiar with grain testing that in order to obtain uniform results the tests must be made in a uniform manner. It is surprising how a slight variation in the method will cause a difference in the result, yet we find that there are many methods in everyday use, when the country as a whole is considered.

VARIATION IN METHODS OF MAKING THE TEST WEIGHT PER BUSHEL OF GRAIN.

Some of the more common methods of testing the weight per bushel are pulling the kettle through the grain until it is full; sinking the kettle part way into the grain and filling it by pulling the grain over the edge by hand, sometimes filling it by a few handfuls and sometimes by several small handfuls; filling the kettle from a bag, pan, or funnel, the bag, pan, or funnel in some cases being held at a height almost even with the top of the test kettle and at other times raised to a height of 10 or 12 inches above the kettle; pouring the grain into the test kettle, sometimes in a thin, small stream, and at other times, in a large, heavy stream; and striking the excess grain off from the kettle with the scalebeam, a sawed-off piece of broomstick, a pencil, or other implement, and occasionally tapping or jarring the kettle before the surplus is struck off or pressing the grain into the kettle before it is struck off. Each of the methods described will give a result all its own. If a given lot of grain were to be tested according to each of the methods mentioned, some of the results would no doubt be similar, if not exactly alike, while others would vary considerably. With such grains as oats, barley, and rough rice, it is a very simple matter to obtain results which vary as much as $1\frac{1}{2}$ pounds

or more per bushel by making the test according to different methods, as is shown in some of the following tables and figures.

Table I shows the variations in test weight per bushel obtained by filling the test kettle by different methods. These tests were all made by the same person, and an attempt was made to make them in exactly the same manner as they had been observed to have been made by various investigators, grain dealers, and grain inspectors while testing grain in commercial work. The tests, with the exception of those made with the aid of a hopper, were all made with an ordinary quart tester and with commercial oats in a railroad car, and so far as possible with the same portion of the grain in the car. The tests made with the hopper were made in the laboratory on samples of the same oats which had been tested in the car by the other methods described.

TABLE I.—*Test weight per bushel of oats, showing the variation in the results obtained by filling the test kettle by different methods.*

| Method of filling the test kettle. | Weight per bushel (pounds). | | | | | | | |
|---|-----------------------------|--------|--------|--------|--------|----------|----------|----------|
| | Individual tests. | | | | | Minimum. | Maximum. | Average. |
| | No. 1. | No. 2. | No. 3. | No. 4. | No. 5. | | | |
| Test kettle filled from a bag held 2 to 3 inches above the kettle..... | 37 | 37.5 | 37.5 | 38.25 | 37 | 37 | 38.25 | 37.45 |
| Test kettle sunk into the grain and grain pulled into the kettle by hand: | | | | | | | | |
| (1) By one motion of both hands..... | 36.5 | 36.5 | 36.5 | 36.5 | 36.25 | 36.25 | 36.5 | 36.45 |
| (2) By 9 to 11 motions of both hands..... | 37 | 37 | 37 | 36.75 | 37 | 36.75 | 37 | 36.95 |
| Test kettle filled by dipping it into the grain..... | 38.75 | 39.25 | 39 | 39.5 | 39.5 | 38.75 | 39.5 | 39.20 |
| Test kettle filled by pulling it through the grain by about a 2-foot sweep: | | | | | | | | |
| (1) Through loose, worked-over grain..... | 38 | 38.25 | 38.25 | 38.25 | 39.5 | 38 | 39.5 | 38.45 |
| (2) Through the packed surface of the grain in a car before the grain had been worked over..... | 39.75 | 40.75 | 39.5 | 39 | 39.75 | 39 | 40.75 | 39.75 |
| Test kettle filled from a hopper having an outlet opening 1½ inches in diameter held 2 inches above the kettle and weighings made on the special beam described in this bulletin. | 37.2 | 37.2 | 37.3 | 37.2 | 37.2 | 37.2 | 37.3 | 37.22 |

Table I shows that the different methods of filling the test kettle resulted in a considerable variation in the test weights that were obtained. The greatest variation in the results of the five tests of any one method was 1.75 pounds; the greatest variation in the averages for the different methods was 3.3 pounds; while the greatest difference in the results of all the tests was as much as 4.5 pounds. The results obtained by the hopper method varied but one-tenth of a pound per bushel in the five tests. Had the tests been made by some other person or by different persons, or had the grain been in different conditions of dryness or cleanness, the results would, no doubt, have varied somewhat from those given in the table. The influence

of moisture content on the test weight of grain is illustrated in figure 1, which shows how a large sample of corn, which was allowed to dry

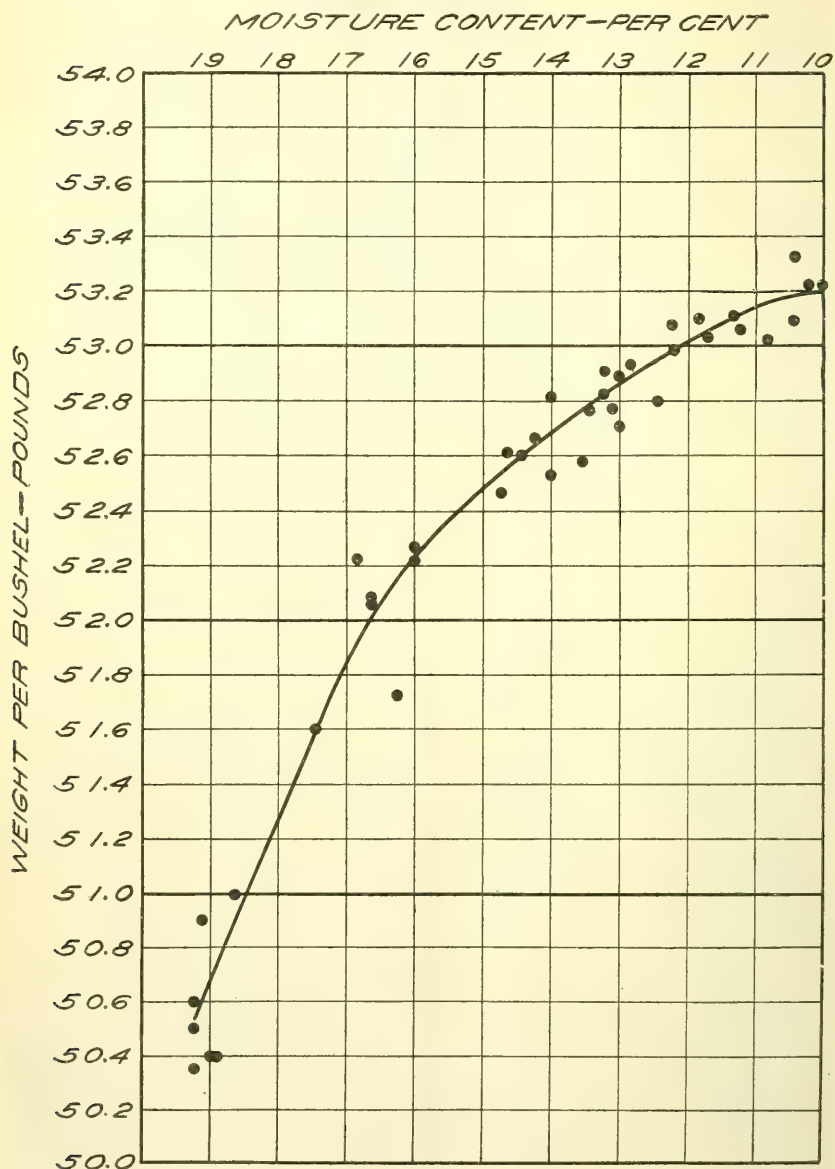


FIG. 1.—Diagram showing how the test weight per bushel of corn increases as the moisture content of the corn is reduced by natural drying.

naturally, increased nearly 3 pounds in test weight per bushel as the corn dried down from a moisture content of slightly over 19 per cent to a moisture content of 10 per cent.

PROPER METHOD OF FILLING THE TEST KETTLE.

Table II gives the results obtained by filling the test kettle from a hopper and shows the influence on the test weight per bushel of (a) the height of the fall, or the distance of the hopper opening above the test kettle, and (b) the size of the grain stream, or the diameter of the hopper outlet opening. These data represent the average results of 10 tests under each condition specified in the tests with the special apparatus described in this bulletin. In making these tests three hoppers were used, having outlet openings 1, 1 $\frac{1}{4}$, and 1 $\frac{1}{2}$ inches in diameter, respectively. A large sample of each of the grains shown in the table was split up into nine equal portions with a sampling device¹ and mixed until each sample showed the same test weight under the same conditions.

TABLE II.—*Test weight per bushel of different grains, showing the influence of the height of fall and of the size of grain stream in filling the test kettle.*

[Average results of 10 tests under each condition described.]

| Grain and diameter of hopper opening. | Test weight per bushel (in pounds) when the distance of the hopper opening above the kettle was— | | | Grain and diameter of hopper opening. | Test weight per bushel (in pounds) when the distance of the hopper opening above the kettle was— | | |
|---------------------------------------|--|-----------|-----------|---------------------------------------|--|-----------|-----------|
| | 2 inches. | 3 inches. | 4 inches. | | 2 inches. | 3 inches. | 4 inches. |
| Flaxseed: | | | | Emmer: | | | |
| 1 inch..... | 52.34 | 52.35 | 52.34 | 1 inch..... | 28.04 | 28.54 | 28.65 |
| 1 $\frac{1}{4}$ inches..... | 52.34 | 52.35 | 52.34 | 1 $\frac{1}{4}$ inches..... | 27.85 | 28.25 | 28.43 |
| 1 $\frac{1}{2}$ inches..... | 52.35 | 52.36 | 52.34 | 1 $\frac{1}{2}$ inches..... | 27.62 | 28.05 | 28.26 |
| Milo: | | | | Corn: | | | |
| 1 inch..... | 59.30 | 59.39 | 59.55 | 1 inch..... | 54.99 | 55.50 | 55.71 |
| 1 $\frac{1}{4}$ inches..... | 59.24 | 59.31 | 59.46 | 1 $\frac{1}{4}$ inches..... | 54.78 | 55.28 | 55.44 |
| 1 $\frac{1}{2}$ inches..... | 59.22 | 59.26 | 59.36 | 1 $\frac{1}{2}$ inches..... | 54.67 | 55.08 | 55.29 |
| Wheat: | | | | Barley: | | | |
| 1 inch..... | 61.20 | 61.32 | 61.45 | 1 inch..... | 47.08 | 47.35 | 47.78 |
| 1 $\frac{1}{4}$ inches..... | 61.14 | 61.25 | 61.34 | 1 $\frac{1}{4}$ inches..... | 46.87 | 47.10 | 47.46 |
| 1 $\frac{1}{2}$ inches..... | 61.08 | 61.16 | 61.20 | 1 $\frac{1}{2}$ inches..... | 46.66 | 46.86 | 47.23 |
| Rye: | | | | Oats: | | | |
| 1 inch..... | 53.98 | 54.12 | 54.20 | 1 inch..... | 37.31 | 37.65 | 38.03 |
| 1 $\frac{1}{4}$ inches..... | 53.88 | 54.00 | 54.05 | 1 $\frac{1}{4}$ inches..... | 37.05 | 37.25 | 37.67 |
| 1 $\frac{1}{2}$ inches..... | 53.81 | 53.92 | 53.98 | 1 $\frac{1}{2}$ inches..... | 36.81 | 37.01 | 37.35 |
| Rice, rough: | | | | | | | |
| 1 inch..... | 43.33 | 43.43 | 43.61 | | | | |
| 1 $\frac{1}{4}$ inches..... | 43.15 | 43.25 | 43.40 | | | | |
| 1 $\frac{1}{2}$ inches..... | 42.85 | 42.95 | 43.24 | | | | |

It will be observed that neither the height of fall nor the diameter of the hopper outlet opening affects the test weight of flax to any appreciable extent, but both factors have a decided and direct influence on the test weight of the other grains, the effect being more noticeable with the large or loose-structured grains than with the

¹ The sampling device used in these experiments is explained in U. S. Department of Agriculture Bulletin No. 287, by E. G. Boerner, entitled "A device for sampling grain, seeds, and other material," issued Sept. 14, 1915. This device has been covered by a public-service patent.

smaller grains of close, compact structure. The data in Table II are illustrated in figures 2 and 3.

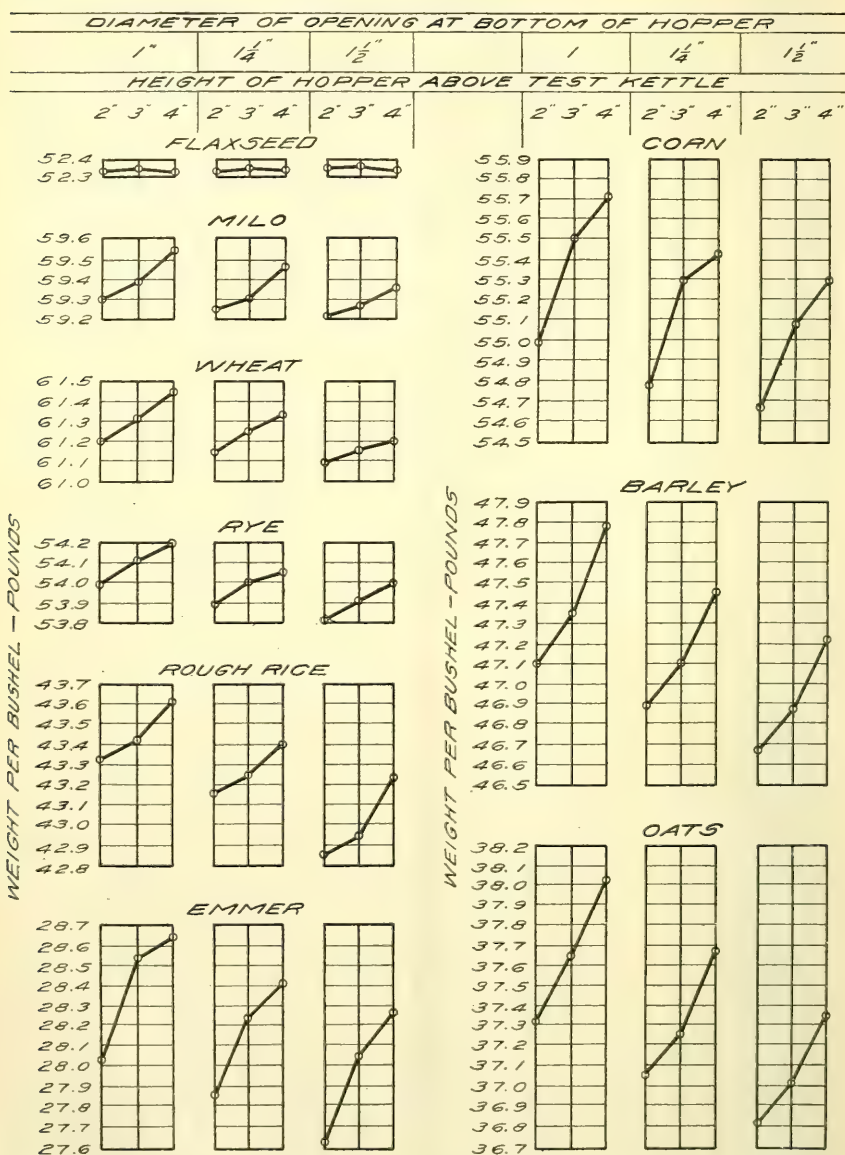


FIG. 2.—Diagram illustrating the influence on the test weight per bushel of allowing grain to fall from varying heights in filling the test kettle, the diameter of the grain stream remaining the same.

Figure 2 shows that the test weights grow heavier as the height from which the grain falls into the test kettle is increased. This result is probably due to the heavier pounding effect on the grain

in the test kettle caused by the increased momentum which the grain receives from a greater distance of fall.

The experiments demonstrated that 2 inches is the shortest distance from the top of the test kettle to the hopper opening which is

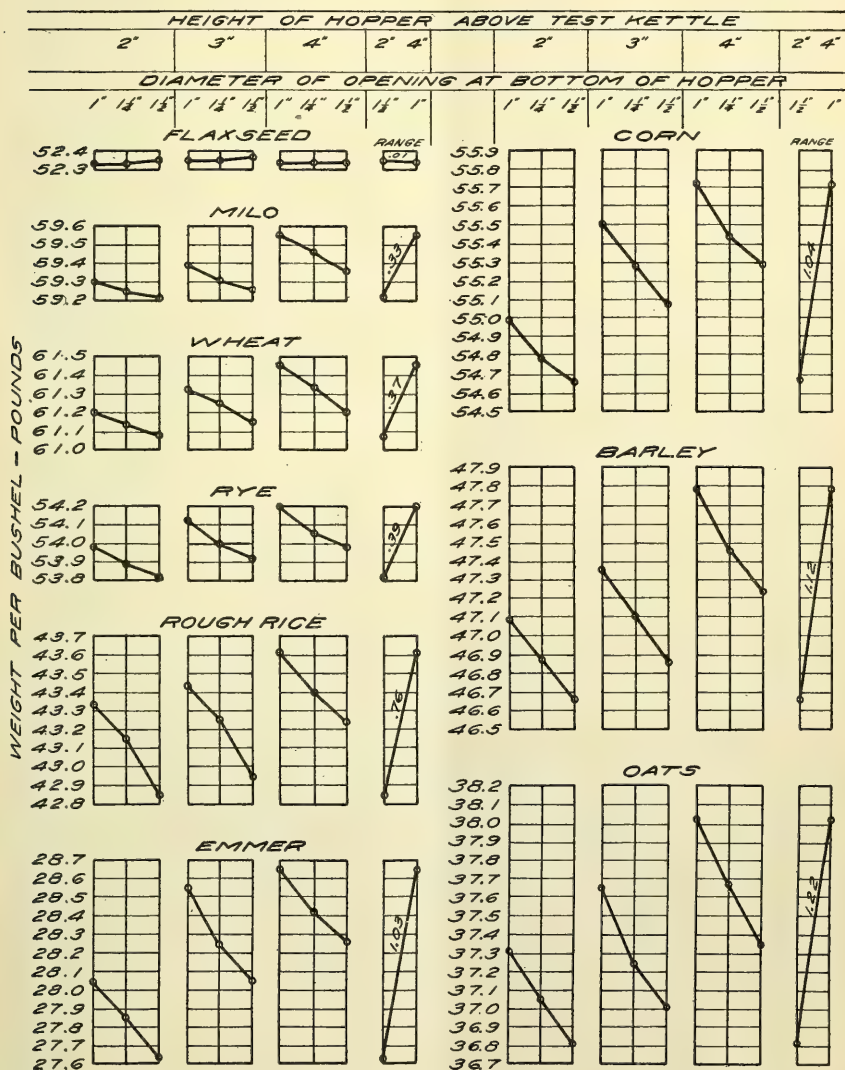


FIG. 3.—Diagram illustrating the influence on the test weight per bushel of filling the test kettle by different-sized grain streams, the height of fall remaining the same.

practicable for all grains, and, as this corresponds with the best trade practices and with the recommendations of the Chief Grain Inspectors' National Association, this has been fixed as the proper height above the kettle from which grain should fall in making the test.

The rule which the Chief Grain Inspectors' National Association has recommended for determining the test weight per bushel of grain reads as follows:

Place the kettle where it can not be jarred or shaken. From scoop, bag, or pan held 2 inches from the top of the test kettle, pour into the middle of the kettle at a moderate speed until running over. Strike off in a zigzag manner with the edge of the beam held horizontally.

It will be seen from figure 3 that with the exception of the tests with flax, the test weight shows heavier as the size of the grain stream or diameter of the opening at the bottom of the hopper is decreased. This result is probably due to the longer pounding effect of the grain when falling in a thin stream.

While the figures show the results for all grains tested by the use of the 1-inch opening in the hopper, the experiments demonstrated that this opening was too small for practical work with such grains as oats, barley, corn, rough rice, and emmer, since these grains run through the 1-inch opening very slowly and frequently clog in the opening and have to be started again with a pencil or by some other means. An opening $1\frac{1}{4}$ inches in diameter was found to be the smallest opening satisfactory for all grains, and as this corresponds very closely with the best trade practices it has been fixed as being the proper diameter for the hopper opening in making tests of weight per bushel of grain.

From what has been stated, it can readily be seen that the test weight per bushel is of vital importance in the buying and selling of grain. It has also been pointed out that, considering the country as a whole, there are many methods of making the test and that serious differences in results occur when different methods are employed. It is generally conceded that standard grades for grain with definite specifications are desirable, and it should be equally apparent that the methods of testing for grade should be put on a standard basis, for unless the same methods of making the tests at the country points and the terminal markets or at different markets are used, widely varying results are sure to be obtained and dissatisfaction will result. To standardize the test, the first essential is the elimination, so far as possible, of the personal error, and to accomplish this result an apparatus having a hopper with a definite-sized opening or outlet at its base, held in place so that this opening will always be at a given distance above the top of the test kettle, appears to be the most feasible from a practical viewpoint, and the apparatus herein described was devised with that feature in view.

DESCRIPTION OF THE DEVICE.

The apparatus (figs. 4 and 5) is in two main parts: (1) The stand, with hopper and overflow pan, and (2) the test kettle, with a special beam. The base of the stand is made up of two layers of wood held together with screws. Each layer is $1\frac{1}{2}$ inches thick, the

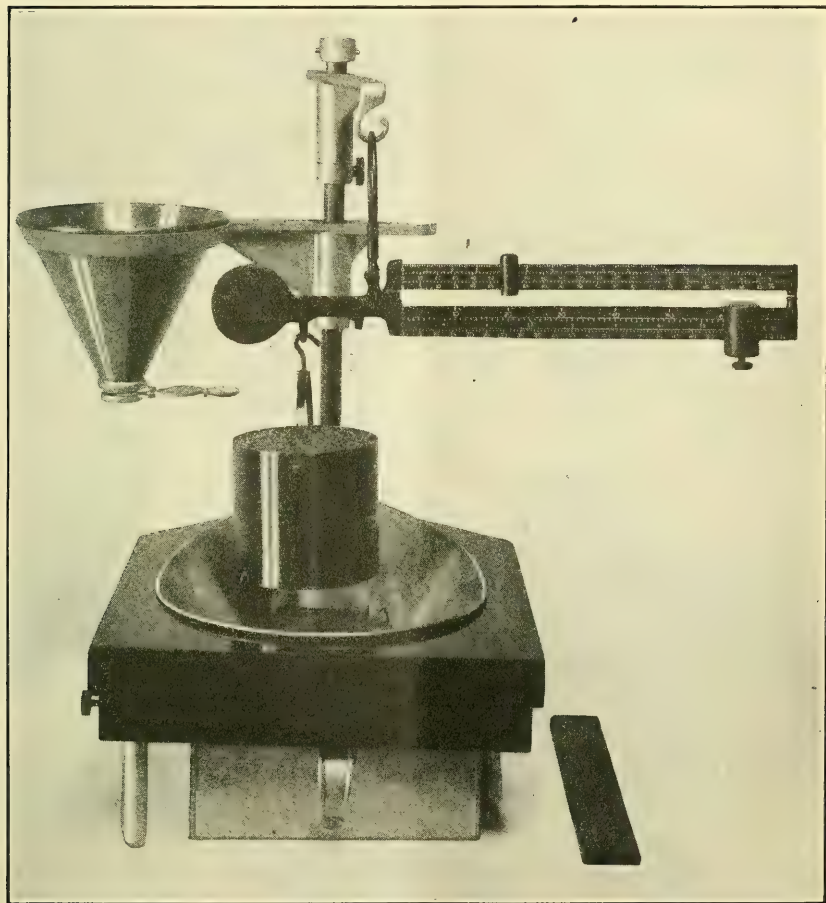


FIG. 4.—Front view of the special apparatus for testing the weight per bushel, showing the hopper swung to the left and a filled test kettle balancing the special beam.

upper layer projecting one-fourth inch over the lower layer around the edges, so that the base can be conveniently fastened into a table top if desired. In the forward part of the base is contained a circular opening with beveled edges, of the shape and size shown in figures 6 and 7. A grate made of four metal bars fastened into the lower layer of the base extends across the opening in the base, as

shown in figure 8. A circular metal disk, or plate, upon which the test kettle rests when in place, is clamped on the upper side of the grating in such a position that the center of the plate coincides with the center of the opening in the base. Two metal guide pins, about 3 inches apart, are fastened to the edge of the plate and then extended upward about half an inch higher than the surface of the

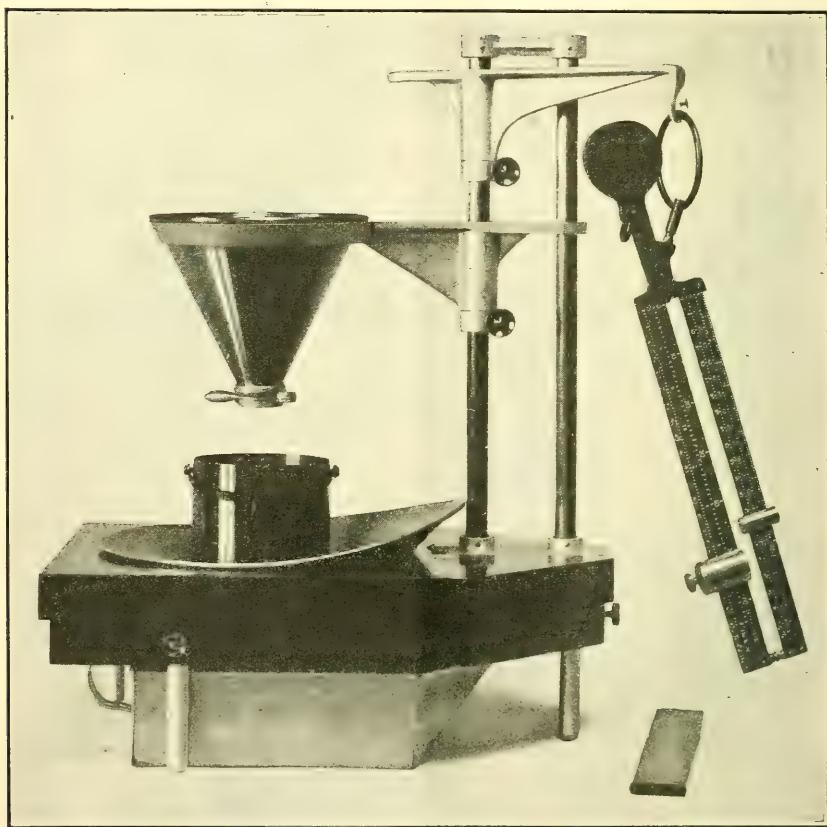


FIG. 5.—Side view of the special apparatus for testing the weight per bushel, showing the beam swung to the right and the hopper and test kettle in place ready for filling the kettle.

plate. These guide pins are placed here to center the quart test kettle when it is in place on the plate. The two guide pins are connected by a strip of metal of the size and shape illustrated in figures 7 and 8. This strip of metal is free swinging, and when swung over on the plate forms a guide for centering the pint test kettle.

Fitted into metal sockets sunk into the after part of the base are two tubular metal posts 19 inches long and connected with a casting

at their upper ends. Fitted to the forward or main post are two free-swinging metal brackets or arms, the lower one of which termi-

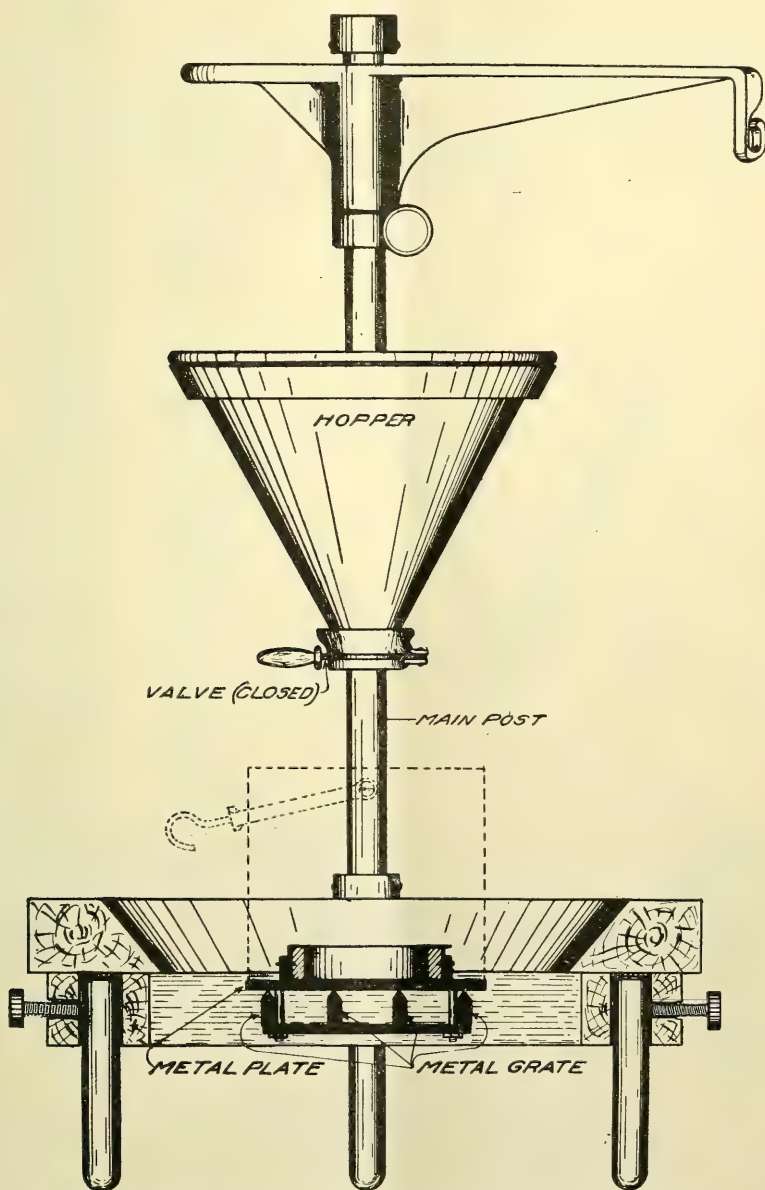


FIG. 6.—Sketch showing how the plate is bolted on the iron grating.

nates in a ring $7\frac{1}{4}$ inches in diameter to hold the hopper, the upper arm terminating in a hook from which the scalebeam can be sus-

pended. The arms are held in place at any given height on the post by means of two metal clamps, as shown in figure 7.

Each of these arms has a projection extending backward past the rear or guide post, so arranged that when the ring of the lower arm and the hook of the upper arm are swung to a position directly over

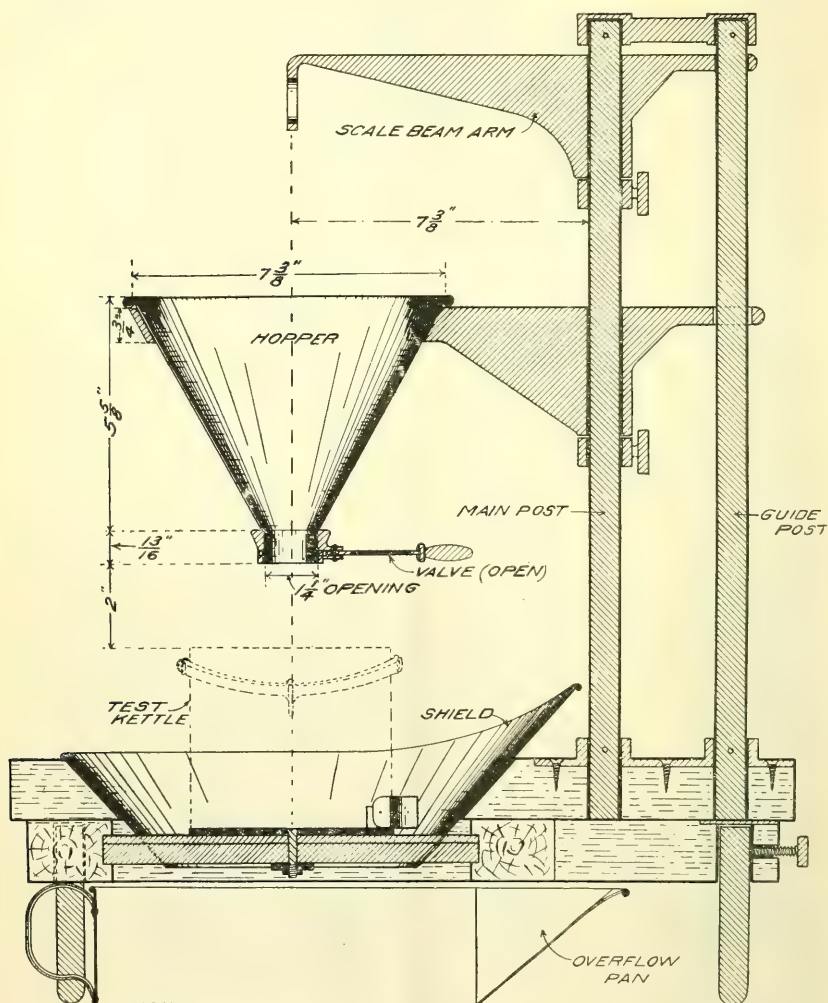


FIG. 7.—Sectional view of the testing apparatus, showing the position of the shield, the grating, and the plate and how the posts and legs are sunk into the framework.

the plate in the base these projections are in contact with the guide post. The projection on the lower arm allows the arm with funnel to swing to the left, while the projection on the upper arm allows this arm with its scalebeam to swing to the right.

The base of the stand rests on three adjustable metal legs which fit into metal sockets sunk into the under side of the base, in the

positions shown in figure 8. The legs are held in place by means of set screws. A pan for catching the overflow from the test kettle is placed underneath the grating.

The hopper, which rests in the ring of the lower arm, is large enough to hold more than a quart of grain and should be of the shape and size shown in figure 7. A valve at its lower opening holds the grain in the hopper until ready to make the test. The opening, or outlet, in the bottom of the hopper is $1\frac{1}{4}$ inches in diameter.

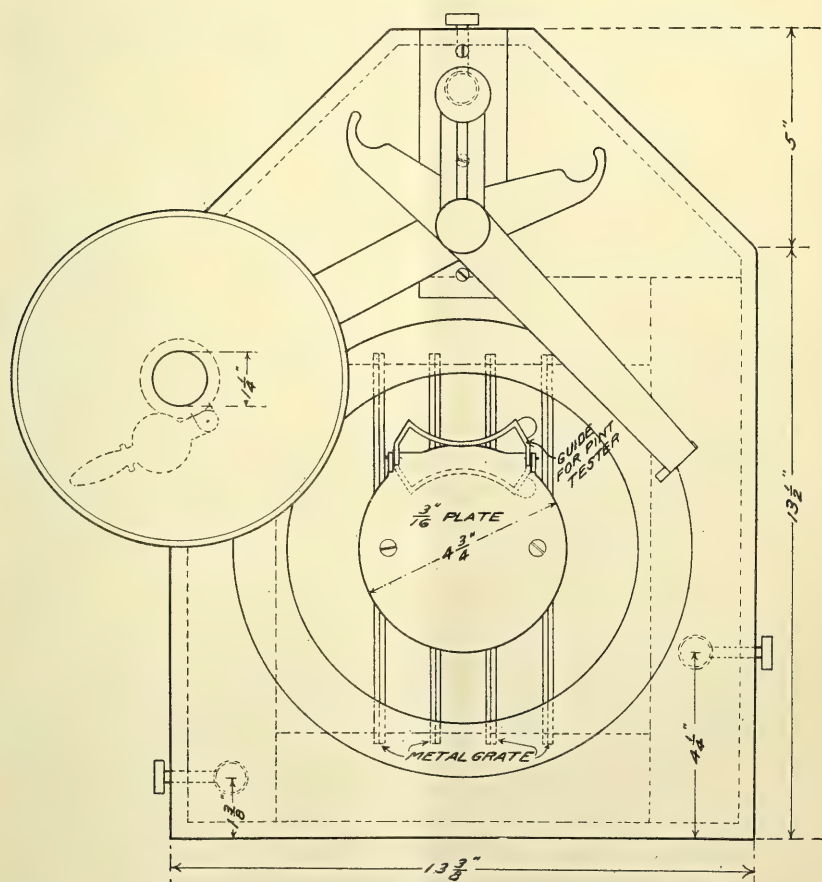


FIG. 8.—Diagrammatic view of the testing apparatus, illustrating the arrangement of the iron grating, the plate, and the guide.

The special stroker is of hard wood, three-eighths of an inch thick, $1\frac{3}{4}$ inches broad, and 12 inches long, each edge being a perfect half circle. This stroker should be used for all tests.

The stand can be used with either the ordinary test kettle and beam or with the test kettle and special combination beam shown in figure 4. The ordinary test kettle and beam, or grain tester, as it is ordinarily called, is well known to the grain trade and needs no

further description. In testing grain for weight per bushel, it is often essential to know the exact weight in fractions of a pound, and this is especially true in the grading of commercial grain, where the rules for the grades specify a minimum test weight which reads in half pounds.

The special beam, graduated to read in tenths of a pound, was devised in order to make it possible to obtain reliable results reading in fractions of a pound. This special beam has two bars, one above the other, each of which has three lines of graduations. The first line on the lower bar reads in pounds per bushel, in divisions of 10 pounds up to 60 pounds; the second line reads in pounds and ounces by one-half ounce divisions up to 2 pounds dead weight, and is used principally for determining "dockage" in grain; the third line reads in percentage of 2 pounds by 1 per cent divisions up to 100 per cent. The first line of graduations on the upper bar reads in pounds and tenths of a pound up to 10 pounds per bushel; the second line reads in grams by 2-gram divisions up to 200 grams dead weight; and the third line reads in percentage of 200 grams by 1 per cent divisions up to 100 per cent. These last two lines of graduations will be found especially useful in the analysis of corn to determine what it should grade from the standpoint of damaged kernels or of foreign matter and finely broken corn.

The poise on the lower bar is supplied with a set screw, so that it can be moved to any one of the 10-pound graduations and clamped in position to keep it from shifting while repeated weighings are being made on the upper beam.

OPERATING THE TESTER.

Place the tester on a solid table top or other firm base. Adjust the height of the funnel arm so that the opening in the bottom of the funnel is exactly 2 inches above the top of the test kettle. Place the test kettle on the metal plate over the grate and see that the overflow pan is in place under the grate opening. Swing the hopper arm into the forward position until the projection extending backward is in contact with the guidepost, when the opening in the bottom of the funnel will be directly over the center of the test kettle. Close the valve in the outlet from the hopper and fill the hopper with the grain or seed to be tested. Open the valve wide with a quick motion and allow the grain to run through until the kettle overflows. Swing the hopper arm out of the way to the left. Strike the excess grain from the top of the test kettle with three zigzag motions of the special stoker, being careful that the sides of the stoker are held in a vertical position and that the kettle is not jarred during the operation. Bring the beam arm with beam suspended into its forward

position. After hooking the test kettle to the short arm of the special scalebeam, the poise on the lower beam must be placed at one of the graduations showing a weight lower than the sample is expected to weigh and the operation is completed by moving the poise on the upper bar to a point necessary to make the beam balance. For instance, wheat usually tests between 50 and 60 pounds per bushel, so that when testing wheat the poise on the lower bar would ordinarily be set at 50 pounds and the weight determined by moving the poise on the upper bar to the necessary position to make the beam balance; if this point should happen to be 7.3 pounds, the test weight of the sample would be 57.3 pounds (50 pounds plus 7.3 pounds).

In testing for weight per bushel of other grains, the poise on the lower bar would ordinarily be set at 30 pounds for oats; at 40 for barley, buckwheat, and rough rice; and at 50 for rye, corn, kafir, milo, feterita, and flaxseed. If the ordinary beam is used instead of the special beam, then the weighing should be done in the usual manner, except that the beam should be suspended from the hook of the upper arm instead of being held by hand. Great care must always be exercised that the beam which is especially adjusted to the particular test kettle with which the test is made be used and that when either the test kettle and ordinary beam or test kettle and special beam are used, the beam must at all times be in balance when the poise or poises, as the case may be, are in zero position.

STANDARD METHOD OF MAKING THE TEST.

The conditions given in the method described below have been found to be most essential in making uniform tests of weight per bushel and obtaining accurate results and have been adopted as standard in connection with Grain Standardization Investigations:

- (1) Have an accurate grain tester.
- (2) Fill the test kettle from a hopper—
 - (a) having an opening $1\frac{1}{4}$ inches in diameter at its base,
 - (b) firmly supported 2 inches above the test kettle.
- (3) Have the test kettle rest on a firm base.
- (4) Fill the kettle each time with the same amount of overflow.
- (5) Strike the excess grain from the top of the overflowing kettle in a uniform manner with three zigzag motions with the sides of the special stoker held vertically, avoiding meanwhile any jarring of the contents.
- (6) Make the weighings on a beam accurately graduated to read in fractions of a pound.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 473

Contribution from the Bureau of Crop Estimates
LEON M. ESTABROOK, Chief



Washington, D. C.



February 12, 1917

PRODUCTION OF SUGAR IN THE UNITED STATES AND FOREIGN COUNTRIES.

By PERRY ELLIOTT, *Division of Crop Records.*

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The ton used in this bulletin is the short ton of 2,000 pounds.

INTRODUCTION.

The data presented in this bulletin cover the period from September 1, 1903, when the Brussels Convention went into effect, to the close of the sugar year 1912-13, with a comparison of the preceding decade.

These two decades exhibit considerable improvement and economic changes in the sugar industry. Prior to the adoption of the Brussels

NOTE.—This bulletin is a concise account of the sugar production of the United States and of practically all foreign countries. It is intended for general circulation.

Convention the beet-sugar industry of Europe had been aided by direct and indirect bounties from the different Governments, which served as a great incentive to the industry. The output of sugar was in excess of domestic requirements and a large quantity had to be marketed abroad. In many instances the sugar was sold in foreign countries at a price less than the domestic price in the country of production. The production of beet sugar had risen to an equal with and in some years had exceeded the production of cane sugar.

Efforts to abolish sugar bounties began as early as 1878, but encountered strong opposition. In December, 1901, the delegates appointed by the different sugar-producing countries of Europe met at Brussels, Belgium, to draft articles of agreement to abolish both direct and indirect sugar bounties. These agreements were adopted and signed on the 5th of March, 1902, and became effective on September 1, 1903. The adhering countries were the United Kingdom, Germany, Austria-Hungary, Belgium, Spain, France, Italy, the Netherlands, and Sweden. Subsequently, Russia, Switzerland, and Peru became members of the convention. The terms of the convention provided for a repeal of all bounty legislation in the countries adhering to the convention and the levying of a countervailing duty on sugar imported from countries that paid a bounty to the industry. The effects of these agreements brought about a reduction in the area planted to beets in 1904 and a consequent decrease in production of beets and sugar. However, these conditions did not continue, for in 1905 and subsequently a general increase in area and production of beets and sugar is shown.

The total world production of both beet and cane sugar has nearly doubled during the last 20 years, increasing from 11,000,000 tons in 1893-94 to 20,000,000 tons in 1912-13. The annual world output of sugar during the decade 1903-4 to 1912-13 averaged 16,419,000 tons, as against 11,498,000 tons for the preceding decade 1893-94 to 1902-3, an increase of 37 per cent. The production of beet sugar for these two periods shows an increase from 5,839,000 tons to 7,853,000, an increase of 34 per cent, as compared with the increase in cane-sugar production from 6,110,000 tons to 8,566,000, an increase of 40 per cent. The increase in the output of cane sugar was largely due to better industrial conditions in Cuba, which resulted in the annual output of sugar being increased from 669,000 tons during the decade 1893-94 to 1902-3 to 1,687,000 tons during the following decade 1903-4 to 1912-13, an increase of 152 per cent. The increase in the output of sugar in Java was also a large factor. The annual production of sugar in that island was 722,000 tons and 1,333,000 tons, respectively, for the two decades just mentioned, or an increase of 85 per cent. The increase in the annual output of beet sugar was confined chiefly to four countries. These countries and their increases

were 487,961 tons for Russia, 371,357 for the United States, 339,839 for Austria-Hungary, and 240,044 for Germany. The annual yield of beets per acre during the decade 1903-4 to 1912-13 for the older beet-growing countries was lower, due mostly to the crop failure in 1911, than for the preceding decade, while the sugar extraction per weight of beets was higher. A very slight increase (0.2 of 1 ton) in yield of beets per acre is shown for the Netherlands and Russia, while Austria gained nearly 1 ton and Hungary more than 1 ton per acre. The decreases are nearly $1\frac{1}{2}$ tons for Belgium, 1 ton for France, and three-fourths of a ton for Germany. During the decade 1903-1912, the yield of beets per acre in the United States was greater than in Hungary and Russia, but less than for the other European countries. The yield per acre during this decade was 13.89 tons for the Netherlands, 12.75 for Germany, 12.67 for Belgium, 11.25 for Austria, 11.23 for Austria-Hungary, 10.98 for France, 9.95 for the United States, 9.86 for Hungary, and 6.90 for Russia. The extraction of sugar per weight of beets was 15.31 per cent for Germany, 15.29 for Austria-Hungary, 15.26 for Belgium,¹ 14.90 for the Netherlands, 13.30 for Russia, 12.15 for the United States,¹ and 12 for France.¹ The increase in production of beet sugar per acre during the decade 1903-4 to 1912-13 over the preceding decade was 594 pounds for Austria-Hungary, 320 pounds for the United States,¹ 195 for Russia, 133 for Germany, and 80 for Netherlands. The annual production of beet sugar per acre during the last ten years was 3,908 pounds for Germany, 3,796 for Belgium,¹ 3,377 for Austria-Hungary, 2,980 for the Netherlands, 2,824 for France,¹ 2,436 for the United States,¹ and 1,849 for Russia. The yield of sugar per ton of beets also shows considerable increase, due largely to improved methods of extraction. The increase in yield of sugar per ton of beets varied from 8 pounds for France to 40 pounds for Belgium. The annual yield of sugar per ton of beets was 306 pounds for Germany, 300 for Belgium,¹ 297 for the Netherlands, 296 for Austria-Hungary, 268 for Russia, and 243 each for the United States¹ and France.¹

The number of beet-sugar factories in each of the beet-growing countries shows a decrease since 1903, except for the United States and Russia. The decrease in number of factories was accounted for by increasing the capacity and improving the methods. Hungary, taken alone, shows an increase, but the decrease in Austria was greater than the total number of factories in Hungary. The annual output of sugar per factory during the decade ending 1912-13 was greater for Hungary than for any other country, amounting to an average of 17,610 tons, as against 5,312 tons for

¹ Refined sugar.

Austria, or 6,615 for the Empire. The average output of sugar per factory for other countries was 7,585 tons for the Netherlands, 7,474 for the United States, 6,170 for Germany, 4,947 for Russia, 3,054 for France, and 2,765 for Belgium. The percentage of increase in the output of sugar per factory during the decade 1903-4 to 1912-13 over the preceding decade was greatest for the United States, amounting to 94 per cent, as compared with 54 per cent for the Netherlands, 41 for Germany, 38 each for Austria-Hungary and Russia, and 20 per cent for Belgium.

Statistics of practically all of the beet-growing countries give the total world area used for beets in excess of 6,000,000 acres, or an average of about 1 ton of sugar per acre of beets. As the average yield of sugar per acre of cane is slightly higher than for beets, it may be assumed that another 6,000,000 acres of cane are harvested for sugar. Thus a total of 12,000,000 acres are harvested annually to produce the world's supply of sugar. In the Tropics the harvested cane is only a part, sometimes about one-half, of the total cane area. The cane growing in all countries in a normal season but not harvested might equal 3,000,000 acres, thus making the total world area of cane possibly 9,000,000 and the total area of cane and beets 15,000,000 acres. The yield of beet sugar per acre has varied from 1,800 to 3,900 pounds, while the cane sugar for countries where reliable data are available varies from 2,000 pounds per acre to more than 9,000 pounds. Hawaii and Java exceeded all other countries in production of sugar per acre harvested, amounting to $4\frac{1}{2}$ tons and 5 tons for some years for Hawaii,¹ as against slightly more than 2 tons for Cuba, 1 ton each for the United States, Porto Rico, Argentina, Australia, and British India. The yield of cane per acre for Hawaii and Java was also higher than for other countries, and averaged about 40 tons, as against about 20 tons for the other countries. As far as data are available, the United States exceeds in production of beet sugar per factory employee, amounting to 59.80 tons annually for the decade 1903-4 to 1912-13, as against 22.97 for Hungary, 20.61 for France, 13.95 for Austria, 11.42 for Russia, and 19.09 for cane sugar for Hawaii.

During the decade 1903-4 to 1912-13 78.9 per cent of the world's output of sugar was produced in 11 countries, compared with 81 per cent for the preceding decade. The 11 countries and the percentage of world's sugar crop produced in each during this decade were 14.5 per cent for British India, 13.6 for Germany, 10.3 for Cuba, 8 per cent each for Austria-Hungary, Java, and Russia, 4.7 each for the United States and France, 3 for Hawaii, and 1.5 each for Belgium and the Netherlands. During this period Germany produced 28.4 per cent of the beet sugar, Austria-Hungary 18.2, Russia 17.4, France

¹ Hawaii, in 1914-15 had 239,800 acres of growing cane, and harvested 113,200 acres, or 47 per cent.

9.9, and the United States 7.3. British India produced 27.9 per cent of the cane sugar, Cuba 19.7, Java 15.6, Hawaii 5.8, and the United States 3.9.

During the decade 1904-1913 the annual exports of sugar from Cuba exceeded all other countries, amounting to 1,626,000 tons; Java, 1,342,000; Germany, 920,000; Austria-Hungary, 755,000; and Hawaii, 482,000. The cane-sugar producing countries show a large increase in exports of sugar, while the beet-sugar countries, with the exception of Russia, show either a small increase or a decrease. The United States exceeded all other countries in imports of sugar, amounting to 2,743,000 tons, as compared with 1,843,000 tons for the United Kingdom, 147,000 for France, 83,000 for the Netherlands, 35,000 for Argentina, and 13,000 for Germany.

The United States also heads the list in consumption of sugar, which amounted to an annual average of 3,492,000 tons during the 10 years 1904-1913, an increase over the preceding decade of 42.9 per cent, as against 2,633,000 for British India; 1,884,000 for the United Kingdom, an increase of 9.9 per cent; 1,203,000 for Germany, an increase of 44.3 per cent; 1,129,000 for Russia, an increase of 49.7 per cent; 662,000 for France, an increase of 37.7 per cent; and 634,174 for Austria-Hungary, an increase of 55 per cent. During the decade 1904-1913 Australia exceeded all other countries in per capita consumption of sugar, amounting to 112.96 pounds, as compared with 85 pounds for the United Kingdom, 77.6 for the United States, 60.6 for Cuba, 38 for Germany, 30.6 for France, 28.1 for Belgium, 26 for Austria-Hungary, 16.7 for British India, and 14.4 for Russia.

The adoption of the articles of agreement at the Brussels Convention brought about a change in the sugar industry of international importance. Eleven years later the outbreak of the European war brought about another change of international importance, the effects of which can not be determined until after the close of the war. The United Kingdom had been the chief market for the beet sugar of the continent. When hostilities began that market not only was closed to most European beet sugar, but the United Kingdom was forced to seek other sources for its sugar supply, which proved to be difficult as well as expensive. The British Empire exceeds all other countries in production of sugar, yet the United Kingdom holds second place in importation of sugar, of which approximately 90 per cent came from foreign countries, mostly European. The West India committee have presented a memorandum to the British Government which cites the advantages of having the United Kingdom obtain its sugar supply from British colonies, which it is estimated could be done if colonial sugar were given preferential treatment in the customs tariff. This legislation, if enacted, will prob-

ably tend to reduce the European beet-sugar output to local requirements and to increase considerably the production of cane sugar.

UNITED STATES.

BEET SUGAR.

Two countries, the United States and Spain, are practically the only countries that produce sugar in considerable quantities from both beets and cane. The beet-sugar industry in the United States is of comparatively recent development. There are two distinct epochs in the history of the industry in this country, the first 1830 to 1888, the second 1888 to the present time. One is characterized by its failures, the other by its success. The first sugar factory was erected in Philadelphia in 1830, but like subsequent enterprises it was unprofitable and was soon abandoned. Efforts were made about every seven years to revive the industry; experiments to locate the territory best adapted to the industry were made in all parts of the country; bounties were granted by some States; but success was not achieved until 1888. As shown by the census in 1909, the industry has been localized in three groups of States: Group I embraces the States of Arizona, California, Oregon, and Washington; Group II, Colorado, Idaho, Kansas, Montana, Nebraska, and Utah; Group III, Illinois, Iowa, Michigan, Minnesota, New York, Ohio, and Wisconsin. During the last decade one State in each of these groups exceeded all the other States in that group, and these three States, California, Colorado, and Michigan, combined, contained three-fourths of the total area under beets and produced three-fourths of the beets and sugar.

The first official record of area devoted to this crop was made for the census for 1899. The area harvested that year was 110,170 acres, which increased to 360,433¹ acres in 1909, or more than three times the area of the preceding census. Three-fourths of the area of beets harvested for each of these two years was located in three States, California, Colorado, and Michigan. The area increased in California from 41,242 acres in 1899 to 83,000 in 1909, and in Michigan from 40,247 acres to 112,232. The growth of the industry has been greater in Colorado than in any other State, as the area in that State increased from 1,094 acres in 1899 to 121,698 in 1909. The area of the United States devoted to the growing of sugar beets in 1909 was less than one-tenth of 1 per cent of the area under cultivation. The area of beets harvested increased from 242,576 acres in 1903 to 555,300 in 1912, or an average of 364,733 for the decade. The increase in area has been gradual, as is shown by the annual average of 228,000 acres during the five years 1901-1904, 374,000 during 1906-

¹ Estimate by Department of Agriculture gives 420,262 acres.

1910, and 543,000 during 1911-1915. The yield of beets per acre increased from 7.2 tons in 1899 to 10.7 tons in 1915. The average yield for the decade ending with 1912 was 9.95 tons, which varied from 8.56 tons in 1903 to 11.26 tons in 1906.

The beets used for sugar increased from 794,658 tons in 1899-1900 to 6,462,000 in 1915-16. The beets used for sugar were 2,076,494 tons in 1903-4 and 5,224,377 in 1912-13, or an average of 3,657,277 for the decade.

The price paid per ton for beets increased from \$4.19 in 1899-1900 to \$5.67 in 1915-16, or an average slightly in excess of \$5 per ton for the period. The total value of beets used for sugar increased from \$10,320,000 in 1903-4 to \$36,919,000 in 1915-16. The value of beets produced, as reported by the census, increased from \$3,323,240 in 1899 to \$19,880,724 in 1909, an increase of nearly 500 per cent. The value of the beet crop compared with the value of all crops increased from one-tenth of 1 per cent in 1899 to four-tenths of 1 per cent in 1909. The value of beets used for sugar increased from \$42.54 per acre in 1903-4 to \$59.62 in 1914-15, or an annual average of \$52.55 for the decade ending with 1912-13. As shown by the census, the value of beets produced per acre increased from \$30.16 in 1899 to \$54.60 in 1909. In 1909 the value of beets per acre was exceeded by four other crops—hops, tobacco, sugar cane, and sweet potatoes. The acre value of beets was nearly four times the value of corn or wheat, and more than four times the average acre value of all cereals.

The season for harvesting beets and making sugar begins in California late in July or early in August and in Utah, Colorado, and States farther east late in September or early in October. The sugar campaign is usually over by January, but may continue even until March. The beets are sometimes kept until time for slicing by siloing them, that is, put in piles with sufficient earth thrown over them to protect them from frost. The average length of the sugar campaign is about 90 days, and varied from an annual average for all factories during the period 1901 to 1915 from 74 to 105 days.

The year 1888 marks the beginning of successful production of beet sugar in the United States. In that year a beet-sugar factory was constructed at Watsonville, Cal. This factory had a daily working capacity of 300 tons of beets per day of 24 hours. In 1890 another factory, with a daily capacity of 300 tons of beets, was erected in Nebraska, and in 1891 three more factories, each with a daily capacity of 350 tons of beets, were constructed—one in Nebraska, one in California, and one in Utah. The number of factories continued to increase to 30 in 1899, 52 in 1905, 73 in 1912, but decreased to 60 in 1914, and in 1915 67 factories were in operation. The majority of the factories have a daily slicing capacity of from 350 to 750 tons of beets. Several factories have a daily capacity of 1,000 tons of beets, one of

2,000 tons, and one of 4,000 tons. The last is said to be the largest beet-sugar factory in the world, and produces daily from 400 to 500 tons of sugar.

The report of the census in 1909 shows a total of 31 factories in 1899, 51 in 1904, and 68 in 1909. Of these factories, 1 was idle in 1899 and 3 in 1909. These factories had a daily slicing capacity of 19,110 tons of beets in 1899, 35,900 in 1904, and 52,750 in 1909. This represents an increase of 119.4 per cent in number of factories and 176.1 per cent in capacity. The people employed numbered 2,321 in 1899, 4,726 in 1904, and 8,389 in 1909, an increase since 1899 of 261.4 per cent. Of the number employed in 1909, 108 were women and 6 were boys under 16 years of age. The number employed during different months of the year ranged from 2,206 in February to 16,807 in November. The capital invested in the industry increased from \$20,141,719 in 1899 to \$55,923,459 in 1904, and to \$129,628,938 in 1909. The quantity of beets used increased from 794,658 tons in 1899 to 3,965,356 in 1909, the sugar produced increased from 81,729 tons to 501,682, and the value of the sugar produced increased from \$7,222,581 to \$45,937,629. The percentage of increase in 1909 over 1899 was: Factories, 93.3 per cent; employees, 216.6; capital, 543.6; value added by manufacture, less cost of materials, 727.6; beets used, 399; sugar produced, 513.8; and value of sugar produced, 536.

Beets for factory use are obtained from two sources—those grown on land owned or controlled by the owners of factories and those grown by independent farmers. The factories planted 17.2 per cent of the area under beets in 1899 and 11.4 in 1909. The factories produced 14.9 per cent of the beets in 1899 and 10.8 in 1909. Better results were obtained by the independent farmers in both years than by the factories. The percentage of area of beets planted by the factories for each year was greater than the percentage of beets produced. In 1909 the Pacific Coast group of States contained 20.7 per cent of the area of beets planted and produced 22.7 per cent of the beets. The Rocky Mountain group contained 47.8 per cent of the area of beets planted and produced 51.4 per cent of the beets. The Great Lakes group contained 31.5 per cent of the area of beets planted and produced 25.9 per cent of the beets. The beets grown in the Pacific coast group of States had a sugar content of 18 per cent of the weight of the beets in 1909, as against 15.1 per cent for the Rocky Mountain group and 16.6 per cent for the Great Lakes group.

Considerable improvement is shown in both quality of beets produced and in the method of sugar extraction since 1901. The percentage of sugar extraction for the United States during the five-year period 1901–1905 was 76.6 per cent, as against 81.5 per cent for the five years 1911–1915. The sugar content for these two periods

shows an increase of 7.6 per cent, compared with 14.5 per cent for sugar extraction, which indicates that the improvement in obtaining sugar from the beet has been nearly twice as great as the improvement in the quality of the beet. A similar comparison of the three principal producing States for the five-year period 1904-1908 with 1911-1915 shows an increase in sugar content of 8 per cent for California, 5.7 for Colorado, and 1.2 for Michigan. The increase in sugar extraction was for California and Colorado each 12 per cent, and for Michigan 2.4 per cent.

The annual production of sugar for the period 1863 to 1887 varied from 100 to 1,200 tons, the average being about 500 tons. In 1888-89 the production amounted to 2,084 tons and gradually increased to 32,726 tons in 1895-96, to 184,606 tons in 1901-2, to 483,612 tons in 1906-7, and to 862,800 in 1915-16. The annual average production of sugar for the decade ending with 1912-13 was 448,346 tons, as against 77,202 tons for the decade ending with 1902-3, an increase of 480.7 per cent.

Comparing the five years 1901-1905 with 1911-1915, the production of sugar increased 202.2 per cent, and the quantity of beets used for sugar increased 166.4 per cent, as compared with 138.5 per cent increase for the area harvested.

The fuel used by the beet-sugar factories in 1909 was mostly coal, amounting to 575,731 tons; oil, including gasoline, was next in importance, amounting to 554,174 barrels; the other fuels were small quantities of coke, wood, and gas. The total value of the fuel used, including rent of power, was \$1,899,468.

CANE SUGAR.

The cane-sugar industry of the United States began about 1794, and has been an important industry for the farmer ever since. The cane is grown in nearly all of the Southern States from North Carolina and Arkansas south, and from the Atlantic coast to Arizona on the west. Arizona produces both beets and cane, and one establishment in that State is equipped with machinery for producing sugar from both of these products. In 1890 cane was grown in seven States, but this number was increased to twelve in 1899 and 1909. The area under sugar cane, as reported by the census, has more than doubled during the last 30 years. The area used for cane was 227,776 acres in 1879, 274,975 in 1889, 386,986 in 1899, and 476,849 in 1909. Louisiana is the principal cane-growing State and contained 80 per cent of the cane area in 1879, 68 per cent in 1889, 72 per cent in 1899, and 69 per cent in 1909. The area under cane in 1909 exceeded the area under beets by 112,756 acres, but the production of beet sugar exceeded that of cane by 167,543 tons. The production of beet sugar

during the last five years has been approximately double that of cane. In 1909 cane was grown on 278,233 farms, compared with 35,682 farms for sugar beets. The custom in Louisiana is to grow two crops of cane from one planting, thus the plowing and planting of cane occurs only every other year on the same piece of ground. The time of planting cane usually begins in September and is completed about the 1st of March. The crop grown from this planting is called "plant cane" and is harvested the following November and December. The crop produced from the preceding year's stubble is called "stubble" or "ratoon" cane, and produces less than the initial crop of plant cane. The production of cane increased from 4,202,202 tons in 1899 to 6,240,260 tons in 1909, of which 74.7 per cent was produced in Louisiana in 1899 and 79.2 per cent in 1909. The yield of cane per acre was 10.9 tons in 1899 and 13.1 tons in 1909. The value of the cane per ton decreased from \$4.89 in 1899 to \$4.23 in 1909, but the total value of cane produced increased from \$20,542,000 in 1899 to \$26,416,000 in 1909. The value of the cane per acre for these two years, respectively, was \$53.08 and \$55.40. Louisiana is the principal cane-growing State and produces nearly all of the cane sugar produced in continental United States. A small amount of cane sugar is produced in Texas, but the cane grown in the other ten States is mostly used for sirup. In point of area in 1909 as compared with other crops, sugar cane was third in Louisiana, being exceeded by corn and cotton, but held first place in value. The total area under cultivation in 1909 was 5,276,016 acres, of which 1,590,830 acres (or 30.2 per cent) was used for corn, 957,011 acres (or 18.1 per cent) for cotton, and 329,684 acres (or 6.2 per cent) for cane. In Louisiana the value of sugar cane exceeded the value of any other crop in 1909, and with corn and cotton formed two-thirds the value of all crops. The total value of all crops was \$77,336,143, of which \$17,752,537 (or 23 per cent) was sugar cane, \$16,480,322 (or 21.3 per cent) was corn, and \$17,324,804 (or 22.4 per cent) was cotton. The area of cane harvested for sugar in Louisiana was 310,000 acres in 1911, 197,000 in 1912, 248,000 in 1913, 213,000 in 1914, and 183,000 in 1915. The yield per acre for these five years was 19, 11, 17, 15, and 11 tons, respectively. Of the 214 cane-sugar factories in operation in 1909, all but 10 were in Louisiana. Of the total number, 192 produced sugar or sugar and sirup, and 22 only sirup. The production of cane sugar per factory was 1,702 tons in 1909, compared with an average production of 8,650 tons per beet-sugar factory. The power of the 214 cane-sugar factories in 1909 was 122,189 horsepower as against 57,202 horsepower for the 68 beet-sugar factories. Practically all of the power in both cases was steam. The number of people employed in the cane-sugar factories in 1909 was 5,313, compared with 8,389 in the beet-sugar factories. The capital invested in the cane-sugar fac-

tories was \$38,000,000, expenses \$26,000,000, and products manufactured \$31,000,000, as against the capital invested in the beet-sugar factories of \$130,000,000, expenses \$37,000,000, and products manufactured \$48,000,000. Of the cane-sugar factories only one reported products in 1909 valued in excess of \$1,000,000, while 14 of the beet-sugar factories reported products exceeding \$1,000,000 in value. From October to January sugar making in the United States is in progress in both beet and cane regions. The smallest number of people employed in each industry in 1909 was in February and the largest number was in November. Most of the cane sugar produced was raw sugar, while practically all of the beet sugar was refined.

In 1909 there were 19 sugar refineries in the United States engaged in the refining of both domestic and imported cane sugar. Louisiana and New York each contained five; California, Massachusetts, New Jersey, and Pennsylvania, two each; and Texas one. These refineries employed 10,345 people and turned out products valued at \$249,000,000.

Of the cane sugar produced in the United States since 1856, 97 per cent was produced in Louisiana and 3 per cent in other States, mostly Texas. During the five-year period 1856 to 1860 the production of cane sugar in Louisiana was 132,402 tons and other States produced 5,978 tons. For the next 15 years the average annual production was less than 100,000 tons, falling as low as 44,768 tons for Louisiana and 3,818 tons for other States. For the next 15 years, 1876-1890, the production for Louisiana was slightly in excess of 100,000 tons and 7,500 tons for other States. For the 10 years 1891-1900 Louisiana produced an average of 276,000 tons and other States 5,500 tons. During the 10 years 1901-1910 the production for Louisiana averaged 350,000 tons and other States 12,900 tons. The largest quantity of cane sugar produced in Louisiana in any one year was 398,195 tons in 1904-5 and was followed closely in 1908-9 by a production of 397,600 tons. During the 11 years 1901-2 to 1911-12 Louisiana produced an average of 349,000 tons of sugar, which fell to 207,000 tons for the next four years. The production of sugar per ton of cane was 120 pounds in 1911, 142 in 1912, 139 in 1913, 152 in 1914, but only 135 in 1915.

A striking contrast is shown in the production of cane sugar compared with beet sugar. The quantity of beet sugar has gradually increased to 862,800 tons in 1915-16, while cane sugar, after an average production of 350,000 tons for the period 1901 to 1911, decreased to 292,698 in 1913-14, to 242,700 in 1914-15, and to 137,500 tons in 1915-16. During the five years 1886-87 to 1890-91 the average annual production of cane sugar exceeded 171,000 tons, as against 1,922 tons for beet sugar. During the five years 1901-2 to 1905-6 the average production of cane sugar was 364,000 tons, as against

240,000 tons for beet sugar. During the next five years, 1906-7 to 1910-11, the average production of beet sugar exceeded the cane by 116,945 tons. The annual production of beet sugar exceeded cane for the first time in 1906-7 and gradually increased to more than six times the cane sugar in 1915-16.

The production of cane sugar in Louisiana as given by A. Bouchereau presents an interesting account of the industry, part of which is not found in other reports. As shown by his report, the area of cane ground increased from 121,991 acres in 1889-90 to 207,674 in 1898-99 and to 216,916 in 1907-8. The cane used for sugar for the same years, respectively, was 2,195,838, 4,361,177, and 4,338,320 tons, and the production of cane per acre for the same years was 18, 21, and 20 tons. There were 746 factories in Louisiana in 1889-90, which decreased to 334 in 1898-99 and to 209 in 1907-8. In 1889-90, 651 of these factories were operated by steam power and 95 by horsepower. The horsepower was gradually displaced by steam power, and in 1901-2 all the factories were operated by steam power. In 1889-90, 590 factories used the open-kettle and open-pan process for making sugar and 156 the vacuum-pan process. The factories using the open-kettle process gradually decreased to 28 in 1907-8, while the factories using the vacuum-pan process increased to 181. The 590 factories using the open-kettle process produced an average of 84 tons of sugar per factory in 1889-90, as against 606 tons for the factories using the vacuum-pan process. In 1907-8 the average was 394 and 1,838 tons, respectively, for these two classes of factories. The 746 factories in 1889-90 produced only 143,746 tons of sugar, compared with 343,755 tons for the 209 factories in 1907-8. The sugar produced per acre by the open-kettle process ranged from 1,431 pounds in 1899-1900 to 2,165 in 1895-96. The production of sugar per acre by the vacuum-pan process varied from 2,560 pounds in 1899-1900 to 3,696 in 1902-3. The production of sugar per acre by the vacuum-pan process from 1889-90 to 1907-8 was nearly twice as much as by the open-kettle process. The production of sugar per ton of cane by the open-kettle process was less than two-thirds of the quantity produced by the vacuum-pan process. The production by the open-kettle process varied from 74 to 109 pounds per ton of cane, while the vacuum-pan process varied from 132 to 168 pounds. The production of molasses increased from 18,431,988 gallons in 1889-90 to 28,069,571 in 1902-3, but decreased to 22,532,774 in 1907-8. Approximately 85 per cent of the molasses was produced by the factories using the vacuum-pan process. The production of molasses by the vacuum-pan process was as low as 26.29 gallons per 1,000 pounds of sugar, while the open-kettle process was as high as 97.61 gallons per 1,000 pounds of sugar. The average production of molasses per ton of sugar by the open-kettle process

was approximately double the quantity produced by the vacuum-pan process.

MAPLE SUGAR.

The United States and Canada are the only two countries for which data relating to production of maple sugar and sirup are available. The territory of the United States devoted to this industry is located in the northeastern part and extends from the Atlantic coast as far west as Missouri and from the Canadian border as far south as North Carolina and Tennessee. The first official figures are the census reports for 1849, which give the production of maple sugar that year as 34,253,436 pounds. Succeeding reports give 40,120,205 pounds of sugar and 1,597,589 gallons of sirup in 1859; 28,443,645 pounds of sugar and 921,057 gallons of sirup in 1869; 36,576,061 pounds of sugar and 1,796,048 gallons of sirup in 1879; 32,952,927 pounds of sugar and 2,258,376 gallons of sirup in 1889; 11,928,770 pounds of sugar and 2,056,611 gallons of sirup in 1899; 14,060,206 pounds of sugar and 4,106,418 gallons of sirup in 1909. The production of sugar has decreased more than one-half since 1849, while the production of sirup has trebled. In 1849 seven States each produced more than 1,000,000 pounds of sugar, compared with only three States producing a like amount in 1909. The seven States and the quantity of sugar produced in each in 1849 were New York, 10,357,484 pounds; Vermont, 6,349,357; Ohio, 4,588,209; Indiana, 2,921,192; Pennsylvania, 2,326,525; New Hampshire, 1,298,863; and Virginia, 1,227,665. The production for those seven States in 1909 was 3,160,300 pounds for New York, 7,726,817 for Vermont, 257,592 for Ohio, 33,419 for Indiana, 1,188,049 for Pennsylvania, 558,811 for New Hampshire, and 44,976 for Virginia. Ohio has been the leading State in the production of maple sirup, producing approximately one-fourth of the total since 1849. The production of maple sirup in Ohio increased from 370,512 gallons in 1849 to 1,323,431 in 1909. The seven other States that produced over 100,000 gallons of maple sirup in 1909 were New York, 993,242 gallons; Vermont, 409,953; Pennsylvania, 391,242; Indiana, 273,728; Michigan, 269,093; Wisconsin, 124,117; and New Hampshire, 111,500. Estimating the quantity of sugar in 1 gallon of sirup to be 8 pounds, the total production of sugar in 1859 was 52,900,000 pounds, compared with 46,900,000 pounds in 1909.

The number of farms reporting maple sugar or sirup made in 1909 was 87,537, as against 62,718 in 1899, or slightly more than 1 per cent of all farms in the United States during both years. The number of trees tapped in 1909 was 18,899,533, of which 5,586,000 were in Vermont, 4,949,000 in New York, 3,170,828 in Ohio, and 1,298,000 in Pennsylvania. The value of the sugar and sirup produced in

1909 was \$5,177,509, compared with \$2,636,711 in 1899, an increase of 96.4 per cent. The average value per farm was \$59 in 1909 and \$42 in 1899. The value of maple sugar produced was \$1,074,260 in 1899 and \$1,380,492 in 1909, compared with \$1,562,451 in 1899 and \$3,797,317 in 1909 for maple sirup. The State of Vermont led all the others in value of maple sugar produced, amounting to 43 per cent of the total in 1899 and 52 per cent in 1909. Ohio was the leading State in value of maple sirup produced, amounting to 39 per cent of the total in 1899 and 28 per cent in 1909. The production of maple sugar in Vermont has decreased nearly one-fourth during the last half century. The production in 1859 was 9,897,781 pounds, compared with 7,726,817 pounds in 1909. However, the production in 1909 was nearly double that of 1899. In 1859 four counties in Vermont each produced more than 1,000,000 pounds of sugar; in 1889 six counties exceeded that figure, and one county produced more than 2,000,000 pounds; in 1909 only two counties exceeded the million mark. For the years 1913, 1914, and 1915 Vermont has tapped annually more than 5,000,000 trees, with 4,700,000 more available but not tapped. The sugar produced in each of the years 1913, 1914, and 1915 exceeded 7,000,000 pounds, and the sirup aggregated 500,000 gallons.

SUGAR SUPPLY.

The sugar consumed in the United States during the last 125 years has been mostly of foreign origin. The West India islands have exceeded all other sugar-growing countries in providing this supply. Of the 9,114 tons imported in 1790, 8,879 tons came from the West Indies. The French West Indies furnished 4,658 tons, and the remainder came from British, Danish, and Dutch possessions in the West Indies. From 1795 to 1808 the imports of sugar were nearly evenly divided, coming from the British, Danish, Dutch, French, and Spanish West Indies. A small quantity also came from British and Dutch East Indies, Swedish West Indies, and the beet-growing countries of Europe. For 1809 and subsequently Cuba, with a few exceptions, was the source of approximately two-thirds of the sugar imported into the United States. For the four years 1897 to 1900 imports of sugar from the Dutch East Indies exceeded the imports from Cuba, and for 1897 and 1899 sugar imported from Germany exceeded the imports from Cuba. The imports of sugar into the United States are practically all raw and have shown a gradual increase from year to year. The imports in 1822 were 25,212 tons, which increased to more than 100,000 tons in 1847, 200,000 tons in 1855, 500,000 tons in 1870, 1,000,000 tons in 1883, 2,000,000 tons in 1902, and 3,000,000 tons in 1914. During the period 1822 to 1839 approximately two-thirds of the total supply of sugar

was imported. From 1840 to 1852 only about one-half was imported, and for 1853 and 1854 less than one-half. For 1855 and subsequently the imports have been approximately three-fourths of the total supply, except for the period 1863 to 1876, when the imports exceeded 90 per cent of the total supply. These imports include the shipments of sugar from the noncontiguous possessions of Hawaii, Porto Rico, and the Philippine Islands to the United States. Imports from these possessions increased from 10 per cent of the total supply in 1865 to 20 per cent in 1909 and to 25 per cent for 1910 and subsequently. The sugar brought from the noncontiguous possessions increased from 35,000 tons in 1865 to 280,000 tons in 1890 and to more than 1,000,000 tons in 1914. During 1912, 1913, and 1914 these possessions supplied one-third of all the sugar imported. The receipts from the noncontiguous territory during the decade ending with 1912-13 increased 138.5 per cent over the decade ending with 1902-3. The receipts from Porto Rico for this period increased 318 per cent, Hawaii 91.6, Philippine Islands 143.3, while the imports from foreign countries increased only 12 per cent. These increases compare favorably with the increase in production in continental United States for this 20-year period. The increase in production of sugar during the decade ending with 1912-13 over the preceding decade was 8.3 per cent for cane sugar and 20.9 for beet sugar. The exports of sugar from the United States have been mostly refined and were sent chiefly to the United Kingdom, Central American States, and the West Indies. The annual exports have exceeded 100,000 tons only four times since 1865, and ranged from 5,000 tons in 1896 to 129,000 tons in 1885 to 275,000 in 1915, and for the 12 months ending June 30, 1916, the exports were 815,076 tons. The exports during the decade ending June 30, 1913, increased 180.4 per cent over the preceding decade.

The United States exceeds all other countries in consumption of sugar, consuming annually nearly one-fourth of the world's production. The consumption of raw sugar increased from 40,612 tons in 1822 to 103,000 in 1838, 341,000 in 1852, 545,000 in 1870, 1,001,000 in 1879, 2,131,000 in 1893, 3,190,000 in 1903, and 4,397,000 in 1914. The per capita consumption of sugar in the United States was exceeded by the United Kingdom, Australia, and New Zealand. The consumption per capita in the United States has increased from 8.9 pounds in 1822 to 34.3 in 1861, but decreased to 17.8 in 1863, and increased to 28.4 in 1866, 40.6 in 1872, 54.2 in 1884, 73 in 1894, 80.4 in 1909, and 89.1 in 1914. The increase in consumption of sugar has been greater than the increase in population. For the decade ending with 1912-13 the total consumption of sugar was 42.9 per cent greater than for the decade ending with 1902-3, as against an increase of 21 per cent for population for the same period. The increase for per capita

consumption was 17.5 per cent for the 10 years 1903-4 to 1912-13 over the preceding decade, compared with an increase of 9.1 per cent of the world crop of sugar consumed in the United States. The percentage of the sugar supply of the United States contributed by domestic production during the decade ending with 1912-13, as compared with the decade ending with 1902-3, increased 36.6 per cent, by noncontiguous possessions an increase of 64.4 per cent is shown, while the percentage contributed by foreign countries decreased 20.9 per cent. Thus it is shown that the domestic production and receipts from the island possessions have gradually replaced the imports from foreign countries; that is, the percentage of the total supplied by foreign countries was lower in the latter decade, being as low as 46.6 per cent, compared with 79 per cent, the highest for the preceding decade.

HAWAII.

The principal industry in the Hawaiian Islands is the growing of sugar cane and the manufacture of raw sugar. About one-fourth of the entire population, slightly less than 50,000 people, are directly engaged in this industry, and the remainder depend upon it to a greater or less extent. The making of sugar practically continues throughout the year, though the greater portion of the crop is harvested from November to July.

The Federal census reported 86,854 acres under cultivation in 1899, of which 65,687 acres, or 75.6 per cent, were planted to sugar cane. The area in cane increased to 186,230 acres in 1909. The total value of all crops in 1899 was \$19,610,551, of which \$18,033,515 was sugar cane. In 1909 the total value of all crops was \$28,535,677, of which \$26,305,747 was sugar cane.

In 1909 the growing of sugar cane was reported by 1,028 farms, and of this number 46 were equipped with mills for making sugar. The production of cane was 2,239,000 tons in 1899, 4,240,238 in 1909, and 4,900,000 in 1913. The yield of cane per harvested acre increased from 34 tons in 1899 to 42 tons in 1911 and to 43 tons in 1913. The annual production of sugar for the last ten years has been about 500,000 tons, ranging from 367,475 tons in 1903-4 to 612,000 tons in 1913-14. The production of sugar per acre harvested increased from 8,253 pounds in 1898-99 to 11,400 pounds in 1914-15. The extraction of sugar per ton of cane was 230 pounds in 1898-99, 249 pounds in 1910-11, and 250 pounds in 1913-14. Practically all of the sugar produced in the islands has been shipped to the United States, aggregating 500,000 tons annually during the last ten years. The annual shipments to the islands from the United States during the same period amounted to more than 1,000,000 pounds of refined sugar. Imports from foreign countries have been about 50,000 pounds annually.

In 1909 there were 46 sugar establishments in the islands, of which 11 produced products that were valued at more than \$1,000,000 each. The largest sugar mill in the islands produced an annual average of 49,513 tons of sugar during the period October, 1903, to September, 1914.

In the sugar industry a large amount of fuel is required, and the refuse (bagasse) from the sugar cane has almost entirely supplied the necessary fuel. As shown by the census of 1909 only a small amount of other fuel was required. The fuel used that year was 4,238 tons of coal, 10,957 cords of wood, and 215,365 gallons of oil, including gasoline.

PORTO RICO.

The making of sugar is the leading manufacturing industry of Porto Rico. The area under cane is exceeded by coffee, but the value of the cane crop in 1909 was nearly three times that of coffee. The total value of all crops in 1909 was \$25,559,265, of which \$13,088,812 was sugar cane. The area of cane harvested in 1899 was 61,556 acres, as compared with 145,433 in 1909 and 211,110 in 1913. In 1899-1900 there were 345 mills in operation, and in 1909-10 this number was reduced to 108, of which only 55 were in operation. The production of raw sugar was about 35,000 tons in 1899-1900 and 346,786 tons in 1909-10, or an increase of nearly tenfold in 10 years. The production of sugar was about 1,000 pounds per acre under cane in 1899-1900, which increased to more than 4,000 pounds in 1909-10. This increase was due partly to a better quality and larger production of cane per acre, but due mostly to improved methods of sugar extraction.

The average number of wage earners employed in the 108 sugar mills in 1909-10 was 5,062. The smallest number employed during any one month was 2,231 in September, and the largest number was 8,403 in March. There are three classes of factories in Porto Rico—the "central" or large mill, the "hacienda" or plantation, which has a small mill for working up the cane grown on the plantation, and the "trapichi" or small mill or grinding plant. In 1913 the average output of sugar per mill was 8,433 tons for the "centrals," 624 for the "hacienda," and 20 for the "trapichi." The "centrals" produced 398,004 tons of sugar, or 97 per cent in 1913, which ranged from 28.50 tons to 51,336.75 tons per factory.

The total production of sugar in 1909-10 was 346,786 tons, or an average per employee of 136,000 pounds for the year.

A large area of "ratoon" or "stubble" cane, that is, cane which has sprouted from the stubble of one or more cuttings, is grown in Porto Rico. The cane is permitted to grow from 4 to 15 years

before replanting. The planting of cane is carried on throughout the year, but the best season for planting is from the middle of September to the middle of January. The crop matures in about 18 months, and the greater portion is harvested during the period from January to June. Practically all of the sugar produced on the island is shipped to the United States, less than 10 per cent being retained for home consumption. The shipments of refined sugar from the United States to the island varied from 1,065 tons in 1903-4 to 8,428 in 1912-13. The annual consumption of sugar varied from 18,000 to 28,000 tons, or a per capita consumption of from 30 to 50 pounds.

PHILIPPINE ISLANDS.

The sugar production of the Philippine Islands has more than doubled during the last 12 years. In 1902-3 the area of sugar cane and the production of sugar were, respectively, 177,628 acres and 198,654 tons, which increased in 1913-14 to 418,676 acres and 408,339 tons.

In 1902-3 two islands, Luzon and Negros, produced 90 per cent of the sugar of the entire Philippine Archipelago. Luzon contained 50 per cent of the area of cane cultivated but produced only 38 per cent of the sugar, while Negros contained only 40 per cent of the area under cane but produced 52 per cent of the sugar. During the same year two Provinces, Occidental Negros and Pampanga, contained 56 per cent of the area under cane and produced 57 per cent of all the sugar produced in the islands. Occidental Negros contained 38 per cent of the area under cane and produced 49 per cent of the sugar, while the Province of Pampanga, in the Island of Luzon, contained 18 per cent of the area under cane but produced only 9 per cent of the sugar.

The cane grown in Negros is apparently much richer in saccharine matter than that from any of the other islands. The average production of raw sugar per acre of cane cultivated in all of the islands was 2,237 pounds, while the average production for Negros was 2,863 pounds, and for Luzon 1,739 pounds. In 1912-13 the production of sugar per acre of cane cultivated for all the islands was 1,585 pounds. For Negros the production was 1,842 pounds, compared with 1,531 pounds for Luzon. In 1913-14 the production of sugar per acre of cane cultivated was 1,951 pounds for all the islands, 2,536 for Negros, and 1,536 for Luzon.

Prior to 1901 the commercial value of the sugar crop of the Philippine Islands was exceeded only by that of manila hemp, but subsequent to 1900 the annual export value of sugar was three-fourths of a million dollars less than that of copra, and was much less than that of manila hemp. The total value of sugar exported during the

period 1901-1913 aggregated \$70,000,000, compared with \$80,000,000 for copra. The value of the manila hemp exported during the same period equaled the value of both copra and sugar.

The five principal crops of the Philippine Islands are hemp (abaca), coconuts, corn, rice, and sugar cane. The total area under cultivation in 1902, as shown by the census, was 3,209,446 acres, or slightly less than one-half of the total area of the islands. The area under the five principal crops in 1902 was 2,813,686 acres, or 87.7 per cent of the area under cultivation. The area of sugar cane cultivated was 177,628 acres, or 5.5 per cent of the area under cultivation, as compared with 45.6 for rice, 16.8 for manila hemp, 11.4 for coconuts, and 8.3 for corn. In 1912-13 the area of the five crops had increased to 5,665,000 acres and increased again the following year to 6,225,000 acres. The value of these five crops at the local markets was \$82,761,000 in 1912-13 and \$78,193,000 in 1913-14.

The area of cane cultivated in 1912-13 was 435,188 acres, which was exceeded by each of the other four crops. In value, at provincial markets, the sugar products held fourth place, amounting to \$12,849,000, or nearly twice the value of the corn. In 1913-14 the area of cane cultivated was 418,676 acres, which was exceeded also by each of the other four crops. In value the sugar products held third place, amounting to \$14,316,000, being exceeded only by rice and manila hemp. The area of sugar cane in 1913-14 decreased nearly 17,000 acres as compared with the preceding year, yet the value of the sugar products produced in 1913-14 was nearly \$1,500,000 more than the previous year.

The production of sugar in 1902-3 aggregated 200,000 tons, which decreased to 168,000 tons in 1909-10, but increased to 345,000 tons in 1912-13 and to 408,000 in 1913-14.

There is a large number of small sugar mills in the Philippines, but the tendency has been toward larger and better equipped plants. There are now three mills, each having a capacity of 1,200 tons of cane per day of 24 hours.

The sugar exported from the Philippines is a low grade of raw sugar and is nearly all sent to the United States. However, for some years China and Hongkong each received more than the United States. The exports to all countries varied from 82,855 tons in 1903-4 to 234,759 tons in 1913-14. The annual average for the 11 years 1903-4 to 1913-14 was 159,093 tons. Only refined sugar has been imported into the islands, amounting to less than 3,000 tons annually. The smallest quantity imported for any one year since 1903 was 1,310 tons in 1905-6, and the largest quantity was 4,862 tons in 1911-12.

The local consumption of sugar has been estimated at about 100,000 tons, or a per capita consumption of 25 pounds. As the quantity of sugar imported is small, a fair estimate of the quantity produced may

be had by adding the estimated consumption of 100,000 tons to the exports, which would give an annual production figure slightly in excess of 200,000 tons for the last 10 years, which was increased to more than 400,000 tons in 1913-14.

CUBA.

The cane-sugar industry of Cuba dates back almost to the discovery of the island. Climatic conditions and soil are well adapted to the growing of sugar cane, with the result that nearly one-half of the cultivated area of the island has been devoted to this crop. The cane matures in from 12 to 18 months. It has been grown in the western Provinces until the land is more or less exhausted and seldom more than 4 or 7 crops are harvested without replanting. In the richer and newer lands of the eastern Provinces 10 or 12 crops and sometimes double that number may be harvested without replanting. The crop is harvested more or less throughout the year, but the principal harvest season is from December to June. In 1899 there were 60,711 farms in Cuba, containing an area of 8,762,000 acres. The area of farm land under cultivation increased from 901,077 acres in 1899 to 2,918,977 acres in 1912, or an increase of 233.9 per cent. The area devoted to cane was 414,202 acres in 1899, 849,000 acres in 1907, and 1,340,139 acres in 1912, an increase of 233.5 per cent since 1899, approximately the same rate of increase as was shown for total land under cultivation. In 1912 56 per cent of the area under cane was either cultivated or controlled by the factory owners and 44 per cent was cultivated by independent farmers who sold their cane to the factories. As an incentive to produce cane rich in saccharine matter the cane is paid for according to the sugar content and not the gross weight.

The sugar factories of Cuba have made considerable improvement in the use of modern equipment during the last few years. Close competition in the sugar market has forced Cuba, as well as other sugar-producing countries, to adopt a more economical method of manufacturing sugar. The result has been an almost constant decline in the number of factories, but an increase in their size and capacity. The number of sugar factories in Cuba decreased from 473 in 1876-77 to 157 in 1900-1901 and increased to 186 in 1906-7, but decreased again to 170 in 1913-14. The average output of sugar per factory increased from 1,231 tons in 1876-77 to 17,008 tons in 1913-14. In 1903-4 the 174 sugar factories in operation used 11,853,129 tons of cane and produced 1,178,546 tons of sugar. The factories each used an average of 68,121 tons of cane and produced an average of 6,773 tons of sugar. Ten years later a smaller number of factories used more than twice as much cane and produced

more than double the amount of sugar. The 171 factories in 1912-13 used 25,137,684 tons of cane and produced 2,737,264 tons of sugar. The average quantity of cane used per factory was 147,000 tons and an average production of 16,000 tons of sugar. During the 10 years ending with 1912-13 there was an average of 175 factories in operation, which ground an average of 15,925,000 tons of cane annually and produced 1,687,000 tons of sugar annually. The average annual quantity of cane used per factory for that period was 91,278 tons, and the average annual production of sugar per factory was 9,680 tons. The extraction of sugar per weight of cane increased from 9.88 per cent in 1903-4 to 11.27 in 1913-14. The lowest percentage of extraction for the period was 9.81 per cent in 1905-6, and the highest was 11.90 per cent in 1908-9. The production of sugar per ton of cane increased from 199 pounds in 1903-4 to 225 pounds in 1913-14, or an average production of 212 pounds for the decade 1903-4 to 1912-13.

In 1912-13 the cane yielded 19.51 tons per acre, and the cane used for sugar amounted to 25,137,684 tons, which was harvested from 1,288,451 acres, compared with 1,340,139 acres planted. The production of sugar per acre was 4,320 pounds. The sugar plantations are equipped with private railway lines to transport cane to the factories from the fields. In 1912-13 the total length of these railways was 2,802 miles, of which 865 miles were standard gauge and 1,937 narrow gauge. There were 15,161 cars and 486 locomotives in use on these railways. The total grinding capacity of the factories in operation, as reported in 1912-13, was 239,195 tons of cane per day of 24 hours. The total quantity of cane ground per day was 205,749 tons, or 84.5 per cent of their nominal capacity. The sugar content of the cane harvested in 1912-13 was 14.17 per cent of the weight of the cane, of which 10.98 per cent was extracted. The "first sugar" produced was 10.57 per cent of the weight of the cane, and the "second sugar" amounted to only 0.41 per cent. The "first sugar" had a polariscopic test of 95.95° in 1912-13 and 96.05° in 1913-14. The "second sugar" tested 89.22° in 1912-13 and 88.70° in 1913-14. Practically all of the sugar produced in 1912-13 was the grade known as "first sugar," which amounted to 10.57 per cent of the weight of the cane, or 2,603,985 tons of sugar. The "second sugar" was only 0.41 per cent of the weight of the cane, or 101,006 tons of sugar. A discrepancy exists in the above figures. The cane used for sugar was stated as 24,635,620 tons, from which the sugar extraction was 10.98 per cent, or 2,704,991 tons. The sugar produced was given as 2,781,046, an increase over the computed figure of 76,055 tons. The molasses produced was 85,581,966 gallons in 1912-13 and 98,607,799 gallons in 1913-14. The fuel used in 1912-13 consisted of 75,629 tons of coal and 400,844 tons of wood.

As a producer of cane sugar Cuba has held second place among the cane-sugar-producing countries of the globe, being exceeded only by British India. For some recent years Cuba has risen to first place. These two countries together produce approximately one-half of the world's supply of cane sugar, each producing from two to three million tons. The Cuban output of sugar was estimated at 224,000 tons in 1839-40, which increased to 500,000 tons in 1859-60, and again increased to 839,000 tons in 1867-68, but on account of the 10 years' war from 1869 to 1878 the production decreased to 582,000 tons in 1876-77 and continued at approximately that figure until 1884-85, when the production amounted to 707,000 tons, and it gradually increased to more than 1,000,000 tons in 1891-92. During the following year the production fell slightly under the million mark, but again exceeded that figure for the two years 1893-94 and 1894-95. On account of the War of Independence and the Spanish-American War, the production decreased to 300,000 tons or less during the period 1896 to 1900. At the close of this last war the business of the island was established on a firmer basis; the production of sugar gradually increased, exceeding 1,000,000 tons in 1902-3, 2,000,000 in 1909-10, and reaching to 2,891,000 tons in 1913-14. The effect of that war is shown in the following figures: During the five-year period of war the production decreased to an annual average of slightly less than 300,000 tons, while during the five-year periods immediately preceding and following the war the average production exceeded 1,000,000 tons, which increased to double that quantity, or more than 2,000,000 tons, for the five-year period ending with 1912-13.

The greater portion of the sugar produced in Cuba is exported, amounting to about 95 per cent during the last 20 years, of which about 90 per cent was sent to the United States. The United Kingdom was the best European customer. These two countries received 99.5 per cent of the sugar exported during the decade ending with June 30, 1913; the percentages were 96.8 per cent to the United States and 2.7 per cent to the United Kingdom. The Cuban consumption of sugar during the decade ending with 1912 was approximately 62,000 tons, or about 60 pounds per capita.

BRITISH WEST INDIES.

The British West Indies hold third place as a sugar-producing possession of the British Empire, being exceeded by Mauritius and British India. Prior to 1900-1901 the British West Indies exceeded Mauritius in the production of sugar, but since that time the production for Mauritius has been much larger, and for some years nearly double that of the British West Indies. The area used for sugar in

the British West Indies in 1902 was approximately 147,000 acres, as against 148,000 acres in 1912-13. The Island of Trinidad has the largest area under cane, or slightly more than one-third of the total cane area of the British West Indies. The average annual area under cane during the decade 1903-1912 was 60,000 acres, compared with 34,000 for Barbados and 29,000 for Jamaica. Statistics of sugar production for St. Lucia, St. Vincent, and the Leeward Islands are lacking, and exports of sugar have been used for those islands. The estimated production of sugar for the British West Indies decreased from 207,716 tons in 1893-94 to 190,341 in 1897-98; increased to 201,595 in 1902-3; decreased to 182,830 in 1903-4, to 169,534 in 1907-8, and to 128,532 in 1912-13. The annual production for the decade 1903-4 to 1912-13 was 161,060 tons, as against 187,920 for the preceding decade, a decrease of 14.8 per cent. The production of sugar in Trinidad during the last 10 years was slightly more than one-third that of all the islands. Barbados produced less than one-third, while the Leeward Islands and Jamaica produced another third. Each of these islands shows a decrease in the output of sugar, which was due in part to diversified farming. In Trinidad the cacao industry has exceeded the sugar industry, while in Barbados, since 1911, the manufacture of sirup and molasses has taken the place of sugar making. The production of "fancy molasses," or sirup direct from the juice of the cane, on this island in 1913 was 8,139,120 gallons, and that of "choice molasses" was 946,880 gallons.

The area of land under cultivation in Trinidad in 1913-14 was 459,675 acres, of which 336,154 acres were used for cacao, 50,742 for sugar cane, and 27,356 for coconuts. The value of the molasses produced in Barbados exceeded \$1,800,000 in 1912 and 1913, while the value of the sugar produced was \$1,500,000 in 1912 and \$441,000 in 1913.

The exports of sugar from the British West Indies decreased from 189,369 tons in 1893-94 to 151,907 in 1895-96, and increased to 167,950 in 1902-3, or an average of 165,311 for the decade. In 1903-4 the exports of sugar were 132,066 tons, which decreased to 110,690 in 1912-13 and to 82,486 in 1913-14, or an average of 135,344 for the decade ending with 1912-13, a decrease of 28 per cent as compared with the preceding decade. The United Kingdom, Canada, and the United States have been the principal markets for West Indian sugar. During the eight years 1895-96 to 1902-3 the annual exports to the United Kingdom were 34,098 tons, or 26.7 per cent, as against 43,191 tons, or 31.9 per cent, for the ten years 1903-4 to 1912-13.

In 1903 the erection of a modern sugar factory was planned at Gunthorpe, on the island of Antigua, and was completed in time to begin operations in 1905. It had its origin in a series of agreements between a group of owners of sugar estates and a company.

in London. The factory was to have a capacity of not less than 3,000 tons of sugar in a season of 100 working days, and the owners of sugar estates were to supply the cane from a stated number of acres for a period of 15 years. During the ten years 1905-1914 the factory crushed 534,988 tons of cane and produced 56,531 tons of sugar. The quantity of cane crushed increased from 17,563 tons in 1905 to 92,994 in 1914. The first year, 1905, the factory produced only 1,830 tons of sugar, which increased to 2,631 the next year, both of which were less than the quantity agreed upon. In 1907 the output of sugar was 4,739 tons, which gradually increased to 10,227 in 1914. The average percentage of sugar extraction per weight of cane for the decade was 10.57 per cent, which varied from 9.52 per cent in 1906 to 11.16 in 1910. The average quantity of cane required to produce 1 ton of sugar during this period was 9.42 tons, which varied from 8.96 in 1910 to 10.51 in 1906.

MEXICO.

CANE SUGAR.

The area upon which sugar cane is grown in Mexico is located in 18 of the 27 States. Some of these States lie along the Pacific and Gulf slopes and others in the interior just south of Mexico City. The entire country is adapted to the growing of cane, except the higher altitudes in the mountain regions and the north-central States. Approximately one-half of the Mexican sugar is produced in two States—Morelos and Vera Cruz. Two other States of importance are Pueblo and Sinaloa. In the State of Morelos rainfall is insufficient and irrigation is necessary to provide sufficient moisture for the growing of crops. The lowlands along the coast are well adapted to the growing of cane, and as many as 10 crops may be harvested from one planting. In the coast regions very little cultivation is needed and the yield has been as high as 35 tons per acre. The sugar industry is in a backward state and very little modern machinery is in use. The old open-kettle process is most in use, which extracts only about 6 per cent of sugar per weight of cane. The area used for cane in 1872 was 6,061 acres, which increased to 174,823 acres in 1909. The production of cane increased from 1,535,047 tons in 1903-4 to 3,044,574 in 1906-7, and the farm value for these two years was approximately \$8,000,000 and \$22,000,000, respectively. The sugar produced decreased from 112,930 tons in 1903-4 to 102,931 in 1905-6, increased to 178,134 in 1910-11, decreased to 167,258 in 1911-12, to 143,000 in 1913-14, and to 121,000 in 1914-15. The percentage of sugar extraction per weight of cane produced decreased from 7.36 per cent in 1903-4 to 4.23 per cent in 1906-7. A small amount of sugar cane grown in Mexico has been sent to the United

States. These exports amounted to 181 tons in 1903-4, 75 tons in 1905-6, 1,301 tons in 1909-10, and 75 tons in 1911-12.

The exports of sugar increased from 17,981 tons in 1903-4 to 42,600 in 1904-5, decreased to 4,643 in 1908-9, and increased to 26,546 in 1911-12. The imports have been less than the exports and increased from 1,419 tons in 1903-4 to 5,649 in 1907-8 and decreased to 1,123 in 1911-12. During the nine years 1903-4 to 1911-12 the annual production of sugar was 125,499 tons, as compared with 14,651 tons exported and 2,301 tons imported. The consumption of sugar annually for the same period averaged 113,149 tons, or 15.25 pounds per capita. The quantity of sugar produced in Mexico has increased more than threefold during the last 15 years. In 1898-99 the production was 55,000 tons, which increased to 178,000 in 1910-11, but, partly on account of the revolution, the production decreased to 121,000 tons in 1914-15. During the five years 1898-99 to 1902-3 the annual production of sugar was 95,900 tons, which increased to 124,000 during the next five years, an increase of 29.4 per cent. During the five years 1908-9 to 1912-13 the annual production was 166,000 tons, an increase of 33.8 per cent over the preceding five years. The sugar produced is practically all raw, mostly in the form of small tablets or cakes.

CANADA.

The beet-sugar industry of Canada was more or less unsuccessful until 1902. The results were so unsatisfactory to both grower and factory owner that the industry was almost entirely abandoned. However, the experience had proved that there were large areas in the Dominion on which sugar beets could be grown successfully and more profitably than other crops.

In 1901 the Legislature of Ontario set apart \$225,000 to promote the growth of sugar beets for a period of three years, not more than \$75,000 to be used in any one year. The act provided for a rate of one-half cent per pound for the first and second years for first-class marketable sugar and one-quarter cent for the third year. These yearly grants provided that not less than \$4 per ton should be paid for the beets delivered at the factories under contract irrespective of the saccharine content for the first year. For the second and third years the price should be 33½ cents per ton for every 1 per cent of sugar in the beets. In 1904, \$150,000 was added to the special fund and authorized a uniform payment of one-half cent per pound for refined sugar for a period of five years. The Alberta Legislature provided for a bonus of one-half cent per pound on refined sugar, produced from beet roots, at the factory for two years commencing in 1906, and one-quarter cent per pound for the three years fol-

lowing. This bonus was to be divided equally between the growers and the company. These factories were provided with machinery to refine raw sugar. Beginning November 30, 1906, additional aid was granted by a reduction in the tariff on imported sugar testing not more than 75 degrees by the polariscope of 31½ cents per 100 pounds and 1 cent for each additional degree.

The total land area under cultivation during the last 10 years aggregated 35,000,000 acres, of which the area under sugar beets varied from 16,200 acres in 1903 to 21,937 in 1911 and fell to 21,000 in 1914. The production of beets varied from 74,444 tons in 1903 to 201,000 in 1912 and 108,600 in 1914. The yield of beets per acre was only 4.60 tons in 1903, increased to 11.03 in 1910, but yielded only 8.98 tons in 1914. The value of the beet crop can be given for only 1908 and subsequently, which amounted to \$578,000 in 1908, increased to \$1,154,000 in 1911, and decreased to \$651,000 in 1914. The average price per ton was lowest, \$5, in 1912, and highest, \$6.59, in 1911.

Five factories began operations in 1903, 4 in Ontario and 1 in Alberta; 2 of the factories in Ontario closed the following year and in 1908 another factory closed, but reopened for the next campaign. The slicing capacity of these factories varied from 500 to 850 tons of beets per day of 24 hours. The output of sugar varied from 7,515 tons in 1903-4 campaign to 13,773 tons in 1914-15 campaign. The sugar content and extraction are available for only 1909-10 and 1910-11 campaigns. The sugar content varied from 15 to 17.26 per cent of the weight of the beets, and the extraction varied from 13 to 14.89 per cent, or from 260 to 298 pounds of sugar to 1 ton of beets. The average length of the campaign varied from 65 to 100 days, beginning in October and ending in January, but the refining of imported raw sugar permitted the factories to operate for a longer time. One of the factories, when employed on raw sugar, had a refining capacity of 350,000 pounds per day of 24 hours.

The exports of sugar from Canada were practically nil, being as low as 2 tons in 1913. The imports varied from 183,630 tons in 1903 to 345,583 in 1914. The consumption of sugar in 1903 amounted to slightly less than 200,000 tons and gradually increased to 359,000 in 1914, or a per capita consumption of 66.6 pounds in 1903 and 92.7 pounds in 1914.

Annual statistics of the maple-sugar industry are not available, but the returns of the last four censuses indicate the annual production to be about 20,000,000 pounds. The production of maple sugar in 1880 was 20,556,049 pounds; in 1890, 25,088,274 pounds; in 1900, 17,804,825 pounds; in 1910, 10,488,340 pounds of sugar and 1,802,581 gallons of sirup. Reckoning 8 pounds of sugar to 1 gallon of sirup, the production in 1910 is equivalent to 24,908,988 pounds of sugar, valued at \$2,587,413.

COSTA RICA.**CANE SUGAR.**

The area of Costa Rica used for the growing of cane lies in the central and Pacific coast region. The total area under cultivation in 1910 was 3,000,000 acres, of which 32,331 acres, or 1 per cent, was in sugar cane. Three other crops exceeded cane in area that year. These crops and their areas were: Coffee, 78,528 acres; corn, 67,910; and bananas, 62,721. About two-thirds of the cane area is located in San José and Alajuela and one-third on the Pacific coast. The cane grown along the coast ripens in about 18 months, while that grown in the higher regions in the interior requires 24 months to ripen. The area used for cane increased from 25,590 acres in 1905 to 27,636 in 1907-8, to 32,331 in 1910, but decreased to 29,474 in 1914. The number of factories decreased from 16 in 1905-6 to 11 in 1914-15. The annual production of sugar during the last 10 years has not exceeded 4,000 tons and varied from 3,360 tons in 1902-3 to 2,751 in 1908-9, to 3,883 in 1911-12, and to 2,926 in 1914-15. The production of sugar is insufficient for domestic requirements, and the imports during the last 10 years varied from 6 tons in 1905-6 to 315 tons in 1912-13 and to 47 in 1914-15.

BRITISH HONDURAS.**CANE SUGAR.**

Statistics of the sugar industry of British Honduras show a decline in both area and production of sugar during the last 20 years. The area in 1893-94 was 1,766 acres, which decreased to 1,412 in 1902-3, to 1,023 in 1905-6, and to 985 in 1912-13. The production of raw sugar increased from 745 tons in 1893-94 to 887 in 1902-3, but decreased to 375 in 1912-13, or an average of 587 for the decade 1903-4 to 1912-13, as against 628 for the preceding decade. The soils best adapted to growing of cane are in the northern and southern part of British Honduras; the soil in the central part is not adapted to the growing of cane and is used for other crops. The production of bananas, coconuts, mahogany, and plantains has taken the place of the sugar industry, but in 1913-14 there were still 14 sugar factories in operation, of which 9 were operated by steam power and 5 by horse power. The United States was the best market for the bananas, but Mexico was the destination for most of the sugar.

ARGENTINA.**CANE SUGAR.**

The first sugar mill was established in Argentina in 1840, and the first vacuum-pan apparatus for making sugar from cane juice was introduced in 1858, but the introduction of improved machinery for

the treatment of cane did not occur until 1879. The territory suitable for the growing of sugar cane is located in the northern part of the Republic, chiefly in the Province of Tucuman. The area under cultivation for all crops increased from 32,000,000 acres in 1905 to 50,000,000 acres in 1911, of which slightly less than one-half of 1 per cent was used for cane. The area under cane increased from 151,406 acres in 1895 to 162,461 in 1905 and to 177,813 in 1912. Approximately 80 per cent of the area used for cane is located in Tucuman. It is the principal crop in that Province and covers about 50 per cent of the area under cultivation. In 1901-2, 54 per cent of the area under cultivation in Tucuman was used for cane, which decreased to 45 per cent in 1904-5 and increased to 66 per cent in 1910-11. In 1912-13 this Province contained 72 per cent of the sugar mills and produced 84 per cent of the cane and 83 per cent of the sugar. The principal harvest season is from June 1 to October 31.

Data showing production of cane are not available, but 2,338,594 tons were used for sugar in 1912-13 and 3,043,389 in 1913-14. The yield per acre is estimated at from 10 to 20 tons. The sugar extraction was 6.9 per cent of the weight of the cane in 1912-13, as against 8.8 per cent in 1913-14. The production of sugar increased from 157,513 tons in 1903-4 to 304,389 tons in 1913-14. The average annual production for the decade ending with 1912-13 was 154,396 tons, compared with 120,798 tons for the decade ending with 1902-3. The number of sugar factories decreased from 51 in 1895-96 to 42 in 1913-14. In 1912-13, 39 mills were in operation and produced 162,313 tons of sugar, or an average of 4,162 tons per factory. The next year 38 mills produced 304,389 tons, or an average of 8,010 tons per factory. The yield of sugar per ton of cane was 139 pounds in 1912-13 and 176 pounds in 1913-14.

The domestic supply of sugar in Argentina since 1895 has been approximately equal to the demand. Prior to that date the imports of sugar nearly equaled the production. During the period 1896 to 1904 a surplus of sugar was produced. The exports for that period amounted to approximately one-fourth of the production and were consigned chiefly to the United Kingdom. For 1905 and subsequently the exports have been practically nil, while the imports have increased.

The sugar imported came chiefly from France, Austria-Hungary, and Germany. The Federal Government has encouraged the industry by paying a bounty on all sugar exported, but has also levied an excise tax on one-fourth of the domestic sugar consumed at home. A maximum price has been fixed by law which is equal to the import duty; when the price of domestic sugar exceeds the price fixed by law, sugar is imported to equalize prices. The imports of sugar were 218 tons in 1903, which increased to 83,289 tons in 1913, but

decreased to 7,234 tons in 1914. The exports decreased from 20,184 in 1904 to 20 tons in 1908 and increased slightly to 66 tons in 1913 and to 71,308 tons in 1914. The small quantity of sugar exported since 1904 was due in a large measure to the agreements signed at the Brussels Convention forbidding the importation of bounty-fed sugar into the countries that became members of that convention. The average annual consumption of sugar in Argentina during the decade 1903-1912 was 182,466 tons, or 17.2 per cent more than the production. The per capita consumption of raw sugar for the same period was 64.1 pounds.

BRAZIL.

CANE SUGAR.

The area upon which sugar cane is grown in Brazil lies chiefly along the Atlantic coast, though cane is grown in nearly all of the States. Three other industries—coffee, rubber, and cocoa—are of much greater importance than sugar, but the output of sugar has been equal to local demands, with some for export. The industry has made less progress in the north, despite the natural advantages, than in the south. Very little sugar is consumed in the northern States, and the most of it produced there must be shipped south either for home consumption or for export. Transportation to the southern States is poor, the rates are high, and labor is scarce, all of which tend to retard the development of the sugar industry in the northern States, yet the northern States produce more than two-thirds of the sugar. Pernambuco alone produces annually as much as all the other States combined.

The factories are of two kinds, "usina" and "engenho." The usinas are the larger factories and have a capacity of crushing from 100 to 700 tons of cane per day of 24 hours. The large or mixed engenho crushes from 50 to 100 tons of cane per day, while the small one ranges from 5 to 50 tons. These factories produce only raw sugar, part of which is refined, but a large portion is consumed without being refined. A good deal of cane is consumed in the raw state, and in the towns freshly expressed cane juice is sold as a beverage.

The cane is planted at the beginning of the rainy season and is harvested from 12 to 18 months later in the southern States and from 11 to 14 months in the northern States. From four to six crops are cut from one planting. The yield of cane per acre varies from 15.61 to 44.61 tons, depending upon the character of the soil and season. The sugar extraction is low as compared with other cane-growing countries and ranges from 4 to 9 per cent of the weight of the cane.

In 1904-5 there were 4,000 sugar factories, of which 160 were usinas, or large mills, and 3,840 engenhos, or small mills. Three-fourths of these mills were located in three States—1,547 in Pernambuco, 857 in Alagoas, and 666 in Sergipe. The total output of sugar for all factories in 1904-5 was 328,485 tons, of which 171,959 tons (or 52.3 per cent) was produced in Pernambuco, 39,683 (or 12.1 per cent) in Alagoas, 33,069 (or 10.1 per cent) in Sergipe, and 29,762 (or 9.1 per cent) in Rio de Janeiro. The production of sugar per factory was largest, 419.18 tons, for Rio de Janeiro; the average was 111.15 for Pernambuco, 49.65 for Sergipe, 46.30 for Alagoas, and 82.12 for all factories in Brazil.

In 1911-12 there were 4,324 factories, of which 134 were usinas and 4,190 engenhos. The output of sugar per factory in the three States of Pernambuco, Alagoas, and Sergipe shows an increase over 1904-5, while a decrease is shown for the factories in Rio de Janeiro. The production of sugar amounted to 330,690 tons, of which 165,345 tons (or 50 per cent) was produced in Pernambuco, 44,092 (or 13.3 per cent) in Alagoas, 33,069 (or 10 per cent) in Sergipe, and 38,580 (or 11.7 per cent) in Rio de Janeiro. The production of raw sugar in Brazil increased from 221,000 in 1903-4 to 343,000 in 1912-13, or an average of 273,000 for the decade. In 1913-14 the production amounted to 228,000 tons, which increased to 269,000 in 1914-15. The production of sugar exceeded 300,000 tons for only three years during the 12 years 1903-4 to 1914-15. The production for these three years was 308,000 tons in 1905-6, 316,000 in 1910-11, and 343,000 in 1912-13. The exports for the decade 1905-1914 amounted to 15 per cent of the production and averaged annually 41,082 tons. The exports of sugar during the decade 1905-1914 decreased 58.1 per cent during the last five years, as compared with the first five, while the production increased 9.2 per cent for the same periods. The imports have been in negligible quantities, and averaged 112 tons annually during the decade 1905-1914. France and Germany were the principal sources for imports of sugar, while the United Kingdom was the chief destination for exports. During this period the annual consumption averaged 232,000 tons, or approximately 20 pounds per capita.

PERU.

CANE SUGAR.

The territory used for the growing of sugar cane in Peru lies chiefly along the Pacific coast, but also a small area east of the Andes Mountains is used for cane. The crop is wholly an irrigated one, as there is very little rainfall. The climatic and soil conditions are well adapted to the growing of cane. The crop is planted and har-

vested throughout the year without interruption, but the principal harvest season is from October to February. The cane in the coast region requires 18 to 20 months to mature and from 8 to 12 crops may be harvested from one planting. The varieties mostly in use were from Java, Peru, Egypt, Louisiana, and Hawaii. The Peruvian variety yielded the largest quantity of cane per acre, but the varieties from Java, Egypt, and Hawaii were richest in sugar.

The area used for sugar cane was 79,072 acres in 1910-11, 91,746 in 1911-12, and 97,743 in 1912-13. The cane crushed amounted to 1,918,028 tons in 1911-12 and 2,056,816 in 1912-13, from which 212,474 and 202,772 tons of sugar, respectively, were obtained. The yield of cane per acre for these two years was 20.91 and 21.04 tons, respectively, and the yield of sugar per acre was 4.14 and 4.09 tons. The percentage of sugar extraction per weight of cane was 11.08 per cent in 1911-12 and 9.86 per cent in 1912-13. The yield of sugar per ton of cane for these two years was 222 pounds and 197 pounds, respectively. The people employed in the Peruvian sugar factories were 16,977 in 1910-11, 19,945 in 1911-12, and 20,942 in 1912-13.

The average production of sugar per employee for these three years, respectively, was 10.15, 10.65, and 9.94 tons. The importance of the coast region as a cane-growing section is shown by the figures for 1912-13. The total production of sugar that year in the 38 factories was 202,772 tons, of which 197,737 tons, or 97.5 per cent, were produced in the coast region, as against 5,035 tons, or 2.5 per cent, for the mountain region. The production has gradually increased from 151,489 tons in 1903-4 to 202,772 in 1912-13, or an average of 176,603 for the decade. The exports decreased from 145,457 tons in 1903-4 to 121,931 in 1906-7 and increased to 194,742 in 1913-14, or an average of 143,742 tons for the decade ending with 1912-13. For this decade the exports amounted to 81.4 per cent of the production.

BRITISH GUIANA (DEMARARA).

CANE SUGAR.

The sugar-cane area of British Guiana is located chiefly in the lowlands along the coast and is protected by massive dykes. The cane areas are all reclaimed land and drained into the sea by the use of steam pumps or by sluices. In 1911 the area of drained marsh land amounted to about 160,000 acres, of which nearly one-half was in cane. The cane is transported exclusively by water along the navigable canals that run through the sugar plantations. Only two or three crops of cane are cut from one planting. Until recent years the Bourbon cane was practically the only variety planted, but that has been supplanted by other varieties, and since 1908-9 the area

planted to Bourbon cane amounted to only about one-third of the total cane area. The Bourbon cane is a product of the island once known by that name but now known as Réunion.

The area used for cane has not increased materially during the last 20 years. It has varied during that time from 66,582 acres in 1897-98 to 78,968 in 1903-4. The annual average area of cane was 69,724 acres for the decade 1893-94 to 1902-3, as against 74,461 for the decade 1903-4 to 1912-13. The statistics of production of sugar are not available prior to 1907-8, but in that year it was stated at 112,825 tons, 149,062 for 1908-9, and 129,071 for 1909-10. The exports of sugar decreased from 114,802 tons in 1893-94 to 94,957 in 1898-99, increased to 141,063 in 1902-3, and decreased to 87,159 in 1911-12. The average exports of sugar were 115,165 tons for the decade 1903-4 to 1912-13, as against 116,427 for the decade 1893-94 to 1902-3. The consumption of sugar in 1909-10 was stated at 8,400 tons, or about 50 pounds per capita. The sugar industry is the leading industry in British Guiana and furnishes employment to about one-third of the population. Other important agricultural products are rice, cacao, rubber, coffee, and coconuts. The sugar produced there is an unrefined product of a slightly yellowish color and known under the trade name of Demarara Crystals. This sugar has a special flavor not found in other sugars and brings a higher price on the English market than any other cane sugar. The three principal markets for that sugar were the United Kingdom, the United States, and Canada.

PARAGUAY.

CANE SUGAR.

The sugar-cane industry of Paraguay is of comparatively recent development and bids fair to be profitable in the future. The supply of domestic sugar has been less than one-half of the nation's requirements. The area devoted to the growing of sugar cane in 1886 was estimated at 7,286 acres and in 1911 the area was said to be about 49,000 acres. Official data are available only for the five years ending with 1914. In 1909-10 there were 16,994 tons of cane used for sugar, which decreased to 10,000 tons the following year and increased to 50,824 tons in 1913-14. The sugar produced amounted to 900 tons in 1909-10, 500 tons in 1910-11, and 2,821 tons in 1913-14. The sugar extraction was slightly more than 5 per cent of the weight of the cane, or about 100 pounds of sugar per ton of cane. The imports of sugar during the five years 1910-1914 averaged 2,312 tons annually, and the average annual consumption was 3,582 tons, or a per capita consumption of about 9 pounds. Exports are given for only one year, 1914, amounting to 464 tons, all of which was sent to Uruguay.

UNITED KINGDOM.

The United Kingdom, though a very small producer of sugar, plays an important part in the international sugar situation. It is the world's second largest sugar market, and it has been the market for most of the sugar exported from the beet-growing countries of Europe. The imports of sugar are exceeded only by those of the United States. The production of beets and sugar are not given, but must be small, as the area planted to beets varied from 51 acres in 1909 to 4,085 in 1913 and 2,334 in 1914. It can be readily seen that the production of sugar from this small area would supply a very small part of the nation's requirements. Practically all of the beets are grown in the county of Norfolk, which also contains the only sugar factory.

The exports of sugar from the United Kingdom consist of sugar that has been imported in the raw state and refined or made into candy. The annual average for the decade ending with 1913 was 34,982 tons, ranging from 50,252 in 1906 to 26,246 in 1913. The imports of sugar consist of nearly equal amounts of raw and refined. The raw sugar imported during the five-year period 1893-1897 constituted 52.1 per cent of the total imports, as against 41.4 per cent for 1900-1904 and 52.6 per cent for 1910-1914. The refined sugar imported since 1893 came chiefly from the beet-growing countries of Europe. Those same countries also supplied approximately one-half of the raw sugar imported. The cane sugar was supplied chiefly by Egypt, Java, Philippine Islands, Peru, Brazil, and the British colonies of Mauritius, British West Indies, and British Guiana. The two principal European countries contributing to the sugar supply were Germany and Austria-Hungary. During the decade 1894-1903 54.5 per cent of the sugar imported came from these two countries, 53.5 from Germany and 1.0 from Austria-Hungary. Also the imports from Java for this period amounted to 1.6 per cent of the total, and Cuba supplied 1.3 per cent. During the next decade, 1904-1913, this condition was changed. The average annual imports of sugar increased nearly 200,000 tons, while the imports from Germany decreased approximately 100,000, or 10.3 per cent. The countries of Austria-Hungary, Java, and Cuba each show a large increase. The annual imports from Austria-Hungary during the decade 1904-1913 compared with the preceding one increased approximately 250,000 tons, or 13.2 per cent. Imports from Java increased 84,000 tons and Cuba 25,000 tons. These four countries supplied slightly less than 60 per cent of the sugar during the decade 1894-1903 and approximately two-thirds during the decade 1904-1913. Germany has been the source of nearly one-half of the sugar supply of the United Kingdom for the last 20 years. During the 10 years ending with 1903 the

sugar brought from Germany amounted to 53 per cent of the total, compared with 43 per cent for the 10 years ending with 1913. The sugar imported from Germany increased from 50 per cent of the total in 1894 to 54 per cent in 1904, but decreased to 48 per cent in 1913. This decrease in imports from Germany was not the result of a new market found elsewhere for German sugar, but to an increased consumption of sugar in Germany, which caused a decrease in exports. This was one of the effects of the Brussels Convention. Export bounties were removed, which forced a reduction in the excise tax, with a consequent reduction in price, thus stimulating home consumption. The loss in imports from Germany was largely made up by Austria-Hungary. Imports from the latter country increased from two-tenths of 1 per cent in 1894 to 18 per cent in 1913. As a result of the European war, an important change occurred in the imports of sugar in 1914. The four countries mentioned above were the source of two-thirds of the sugar supply of the United Kingdom that year. Germany and Austria-Hungary were the source of one-half of this amount, while Java and Cuba were the source of the other half. The customary amount formerly received from Germany and Austria-Hungary was reduced approximately one-half in 1914. This shortage in the sugar supply from Europe was made up by increased imports from Cuba and Java. An interesting comparison is shown in imports of sugar in 1915 compared with 1913. The imports in 1913 were 2,205,571 tons, as against 1,659,992 in 1915. The value increased from \$112,000,000 in 1913 to \$155,000,000 in 1915, or an increase in the import price from 2.6 cents per pound in 1913 to 4.7 cents in 1915. The imports from European countries decreased from 1,797,150 tons in 1913 to 107,924 in 1915, while imports from foreign countries and British Colonies increased from 408,421 tons in 1913 to 1,552,068 in 1915. The British Empire exceeds all other countries in the production of sugar, yet the British colonies have supplied less than 9 per cent of the sugar imported into the United Kingdom during the last 20 years, and for the five years 1900-1904 the imports from the colonies were a trifle less than 5 per cent of the total. The value of the sugar imported has aggregated \$100,000,000 annually during the last 20 years, the yearly range being from \$91,000,000 during the five years 1893-1897 to \$128,000,000 for the five years 1910-1914.

With the exception of the United States, the United Kingdom consumes more sugar than any other country. The consumption has increased gradually from 1,552,655 tons in 1894 to 2,205,983 in 1914. The per capita consumption varied from 79.91 pounds in 1894 to 95.70 pounds in 1914, which exceeds all countries except Australia and New Zealand.

GERMANY.

BEET SUGAR.

The areas devoted to the growing of sugar beets in Germany are widely scattered throughout the Empire, but the principal area is confined to three sections—the central, northern, and southeastern. In 1912–13, 50 per cent of the total area in sugar beets was located in three provinces—22 per cent in Saxony, 15 per cent in Silesia, and 13 per cent in Posen. In point of area in 1913 the sugar-beet crop was exceeded by five other crops. The crops in their order were rye 16,000,000 acres, oats 11,000,000, potatoes 8,000,000, wheat 5,000,000, and barley 4,000,000, as compared with 1,353,000 for beets.

The area devoted to sugar beets has shown a slow but gradual increase. Since 1897 the annual area devoted to this crop has exceeded 1,000,000 acres. In 1901–2 the area was 1,182,989 acres, which decreased to 1,056,708 acres in the following year. Although there was almost a gradual increase, the area did not reach the 1901–2 figure again until 1911–12, when the area was 1,353,181 acres, which decreased the following year to 1,316,655 acres. The average area of beets harvested annually for the ten years 1903–4 to 1912–13 was 1,143,208 acres, compared with 1,056,065 acres for the 10 years 1893–94 to 1902–3. This represents an average annual increase of 8,714 acres during the 10 years subsequent to the Brussels Convention compared with the 10 years preceding the convention.

The production of beets in 1901–2 was 17,650,983 tons, which exceeded the production for any year prior to 1912–13. In the latter year the production was 18,344,738 tons, which increased in 1913 to 18,672,939 tons. The average annual production for the 10 years 1903–4 to 1912–13 was 14,583,883 tons, compared with 14,162,151 tons for the preceding decade.

The average annual production per acre for the decade 1903–4 to 1912–13 was 12.75 tons, compared with 13.41 tons for the decade 1893–94 to 1902–3. The decrease in the latter decade is due chiefly to the low yield of 8.03 tons in 1911–12. The low average yield that year was caused by a severe drought that affected all of the crops of western Europe. If the yield in 1911–12 had been normal—that is, 6 tons more per acre—the 10-year average would have been 13.35 tons, or practically the same as the preceding decade. The highest average production of beets per acre for any one year was 14.92 tons in 1901; this was followed closely in 1905 by 14.90 tons and in 1910 by 14.72 tons. The farm value per ton of beets has increased from \$3.84 per ton in 1903–4 to \$5.42 in 1911–12, or an average for the decade of \$4.56. The value of beets per acre ranged from \$52 in 1903–4 to \$70 in 1912–13. The year of 1911–12 was noted for two characteristic features: The price paid the grower, \$5.42, for beets

was the highest for the decade, while the value per acre, \$44, was the lowest for the decade. The average value per acre for the entire period was \$58.

The beets for German factories are obtained from three sources, and are defined as factory beets, stockholders', and purchased beets. The factory beets are grown on land owned or leased by the factory; the stockholders' beets are grown by individual members of agricultural societies, who own the most of the sugar factories; and the purchased beets are bought in the open market and are grown by independent growers and stockholders not on contract. Beets grown on contract are usually from one kind of seed, supplied gratis by the factory with which the contract is made.

A striking comparison is shown in the production of beets by the three classes of beet growers. The percentage of area cultivated by each class of growers was practically the same as the percentage of production of beets by each class. Expressed as percentages of the total area under beets, the area grown by the factories was 6.5 per cent, stockholders' and other contract beets 39.5 per cent, and independent growers 54 per cent. The quantity of beets produced was 6.7 per cent by the factories, 39.4 per cent by the stockholders, and 53.9 per cent by the independent growers. The average productions per acre by the three classes of growers were remarkably uniform. The factories produced an average for the decade 1903-4 to 1912-13 of 13.04 tons per acre, stockholders 12.72 tons, and independent growers 12.75 tons.

The area and production of beets and sugar have gradually increased for a number of years, but the number of sugar factories has gradually decreased. This would indicate that the factories have been increased in capacity. During the decade ending with 1912-13 the factories decreased from 384 in 1903-4 to 342 in 1912-13. In 1874-75 there were 332 factories, which gradually increased to 468 in 1893-94 and then decreased to 342 in 1912-13, or a loss of 126 factories in the last 20 years. The average number of factories in operation during the decade ending with 1912-13 were 362, compared with 456 for the preceding decade. The average annual output of sugar per factory during the decade ending with 1912-13 was 6,170 tons, compared with 4,372 tons during the previous decade. The production of sugar per factory increased from 4,428 tons in 1904-5 to 8,484 in 1912-13. The production of raw sugar increased from 2,008,932 tons in 1903-4 to 2,901,564 in 1912-13, or an annual average for that period of 2,233,553 tons, compared with 1,993,509 tons during the preceding 10-year period. The production of raw sugar per ton of beets varied from 285 pounds in 1903-4 to 316 in 1912-13. The highest average production per ton of beets during the period 1903-4 to 1912-13 was 335 pounds, compared with 317 pounds for

the preceding 10 years. The annual average production per ton of beets during the decade 1893-94 to 1902-3 was 280 pounds, compared with 306 pounds for the following decade.

In addition to the factories producing sugar from beets, there were six factories that produced sugar from molasses. The molasses remaining at the beet factories was sent to the molasses factory to be further treated. This process resulted in the production of a large quantity of sugar which materially assisted in increasing the value of the factory products. The molasses remaining after this treatment is further used for stock feed, fertilizer, and chemicals. The average annual production of molasses by the sugar-beet factories during the decade 1903-4 to 1912-13 was 335,546 tons. The raw sugar from the beet factories is sent to the refineries for further treatment, after which it is released for home consumption and export. The number of refineries decreased from 48 in 1904-5 to 31 in 1912-13.

The sugar production of Germany is far in excess of the nation's requirements, but the surplus has decreased during the last 20 years at the rate of 42,000 tons annually. During the decade ending with 1912 the exports amounted to 41.3 per cent of the sugar produced, or an annual average of 920,262 tons. The exports for the preceding decade were 1,161,620 tons, or 58.3 per cent of the production. The imports for both decades were small, but decidedly greater in the last decade than in the one preceding. The imports for the decade ending with 1912 were 13,353 tons, compared with 1,614 tons during the preceding decade. The consumption of sugar has more than doubled during the last 20 years, and increased from 569,481 tons, or a per capita consumption of 22.3 pounds in 1893-94 to 1,413,489 tons, or a per capita consumption of 42.3 pounds, in 1912-13. The annual average consumption during the decade 1903-4 to 1912-13 was 1,202,902 tons, or an average of 38 pounds per capita, compared with 707,506 tons, or 25.8 pounds per capita, for the preceding decade. Expressed as a percentage of production the consumption during the 10 years ending with 1912-13 was 53.9 per cent, as compared with 35.5 for the preceding 10 years. The increase in consumption was due partly to a reduction of the sugar tax, with a consequent lowering of the retail price, and to the rapid growth of chocolate, cocoa, and other sugar-consuming industries.

AUSTRIA-HUNGARY.

BEET SUGAR.

The area devoted to the growing of sugar beets in Austria-Hungary is located principally in the western and northwestern part of the Empire. The total area under cultivation during the decade

1903-1912 was 62,000,000 acres, of which 871,986 acres, or 1.4 per cent, was used for sugar beets. During this period 67.1 per cent of the area under beets was located in Austria and 32.9 per cent in Hungary. The area under beets decreased from 871,294 acres in 1893 to 711,784 in 1902 and increased to 1,088,088 in 1912. The average annual area under beets during the decade 1903-1912 was 871,986 acres, compared with 787,286 acres for the decade 1893-1902, an increase of 10.7 per cent. The production of beets was 5,439,735 tons in 1883, 7,142,514 in 1893, 8,196,853 in 1903, and 14,069,183 in 1912. The annual production of beets during the decade 1893-1902 was 7,791,509 tons, which increased to 9,488,812 for the decade 1903-1912, an increase of 21.8 per cent, as against an increase of 10.7 per cent for area under beets. The production of beets per acre increased from 8.2 tons in 1893 to 10.3 tons in 1902 and 12.93 tons in 1912. The average annual production of beets per acre increased from 9.9 tons during the decade 1893-1902 to 10.88 tons during the decade 1903-1912, an increase of 9.9 per cent.

The factories in operation decreased from 230 in 1903-4 to 214 in 1912-13, or an average of 217 for the decade. The beets used for sugar varied from 8,500,661 tons in 1903-4 to 13,911,305 in 1912-13, an average of 9,707,797 tons for the decade. The average annual quantity of beets used was 5,799,503 tons for the decade 1883-84 to 1892-93, 8,374,545 tons for the decade 1893-94 to 1902-3, and 9,707,797 tons for the decade 1903-4 to 1912-13. The sugar produced increased from 1,230,087 tons in 1903-4 to 2,093,439 in 1912-13, or an average of 1,435,525 for the decade. Comparing the area of beets harvested annually during the decade 1903-4 to 1912-13, an increase of 10.8 per cent is shown over the decade 1893-94 to 1902-3, and an increase of 35.5 per cent over the decade 1883-84 to 1892-93. The beets used for the same periods increased 15.9 per cent and 67.4 per cent, while the sugar produced increased 31 per cent and 115.7 per cent, respectively. The beets used per factory were 44,736 tons during the decade 1903-4 to 1912-13, as against 36,570 tons for the preceding decade. The production of sugar per factory for these two decades was 6,615 and 4,785 tons, respectively. Austria far outranks Hungary in the production of beets and sugar, but the increase during the last 20 years has been much greater for Hungary than for Austria. During the ten years 1893-94 to 1902-3 Austria contained 74.1 per cent of the area of beets harvested in the Empire, produced 77 per cent of the beets and 81.6 per cent of the sugar. During the next decade, 1903-4 to 1912-13, Austria contained 67.1 per cent of the area of beets harvested, producing 69.6 per cent of the beets and 71.8 per cent of the sugar. The sugar extraction per weight of beets increased from 13.08 per cent for the decade 1893-94 to 1902-3 to 15.29 per cent dur-

ing the decade 1903-4 to 1912-13. The average production of sugar per ton of beets increased from 262 to 296 pounds for these two decades, respectively. The average production of sugar per acre for the same periods was 2,783 and 3,377 pounds. Of the 217 factories in Austria-Hungary in operation during the decade 1903-4 to 1912-13, 194 were in Austria, but they are much smaller than the Hungarian factories. During this period the average area of beets per factory was 3,014 acres for Austria and 12,487 for Hungary. The Austrian factories each annually used an average of 36,895 tons of beets and produced an average of 5,312 tons of sugar. The Hungarian factories each used annually 110,881 tons of beets and produced 17,610 tons of sugar, a little more than three times the amount produced by the Austrian factories.

The consumption of sugar in Austria-Hungary has more than doubled during the last 20 years. The consumption was 354,105 tons in 1892-93, which increased to 756,300 tons in 1913-14. The average consumption of sugar for the five years 1898-99 to 1902-3 was 428,007 tons, which increased to 705,918 tons during the five years 1909-10 to 1913-14, an increase of 64.9 per cent. The per capita consumption increased from 18.5 pounds in 1900-1901 to 29.8 pounds in 1910-11.

The imports of sugar into Austria-Hungary have been small, but have increased from an annual average of 39 tons during the decade 1884-1893 to 167 tons for the decade 1894-1903 and to 930 tons for the decade 1904-1913. The exports have more than quadrupled during the last 30 years, and have increased from 280,200 tons in 1884 to 1,184,383 tons in 1913. During the decade 1894-1903 the annual exports were 693,711 tons, as against 378,282 for the preceding decade, an increase of nearly 100 per cent. During the decade 1904-1913 the annual exports were 754,721 tons, as against 693,711 for the preceding decade, an increase of only 8.8 per cent. Thus the exports during the 10 years since the adoption of the terms of the Brussels Convention show a much smaller percentage of increase than for the 10 years preceding the convention. The percentage of the sugar crop exported increased from 56 per cent during the decade 1884-1893 to 63.1 per cent for the decade 1894-1903, but decreased to 52.6 per cent for the decade 1904-1913. For the last 20 years and more the United Kingdom has been the principal market for Austro-Hungarian sugar, receiving as much as all other countries combined. During the decade 1893-1902 that country received 46.4 per cent of the exports of sugar from the Dual Monarchy, which was equivalent to 28.3 per cent of the sugar output. During the decade 1903-1912 the United Kingdom received 48.9 per cent of the sugar exported, which was equivalent to 27.9 per cent of the sugar produced during that period.

AUSTRIA.

BEET SUGAR.

The principal sugar-producing area of Austria-Hungary for a number of years has been located in Austria. This Empire contained two-thirds of the area of the Dual Monarchy devoted to sugar beets during the last 10 years, and produced more than three-fourths of the beets and sugar. The principal beet-producing area is in the western part, in the Provinces of Bohemia, Moravia, and Lower Austria. During the 10 years 1903-1912 Bohemia contained 58.4 per cent of the area of Austria under beets and produced 61.3 per cent of the beets; Moravia contained 31.8 per cent of the area, but produced only 14.4 per cent of the beets; Lower Austria contained 5.3 per cent of the area and produced 3.9 per cent of the beets. The total area of Austria under cultivation during the decade 1903-1912 was 27,000,000 acres, of which 584,787 acres, or 2.2 per cent, was devoted to sugar beets. The area under beets has not increased materially during the last 20 years. The annual average during the decade 1893-1902 was 583,496 acres, as against 584,787 for the decade 1903-1912, an increase of only 0.2 per cent. The production of beets for the same period increased 10.1 per cent and the output of sugar increased 15.3 per cent. These percentages are in wide contrast to the same data for Hungary, where the increases for the same periods were 40.9 per cent for area, 61.1 per cent for beets produced, and 100.5 per cent for the output of sugar. The yield of beets per acre in Austria increased from 11.49 tons in 1903 to 13.36 in 1912, or an average of 11.25 for the decade.

The number of factories in Austria decreased from 209 in 1903-4 to 186 in 1912-13. The beets used for sugar increased from 6,473,668 tons in 1903-4 to 9,370,873 in 1912-13, or an average of 7,157,539 for the decade, which was 8.4 per cent more than was produced. During the 10 years 1903-1912 Austria-Hungary imported annually 64,902 tons of beets, valued at \$285,283. These beets were mostly worked up in Austrian factories and came chiefly from Germany. The sugar output of the Austrian factories increased from 896,055 tons in 1903-4 to 1,441,152 in 1912-13, or an average of 1,030,476 for the decade. The sugar extraction of beets grown in Bohemia was higher than for any other Province in the whole Empire. The average sugar extraction for Bohemia for the decade 1903-4 to 1912-13 was 15.9 per cent of the weight of the beets. The lowest extraction for the decade was 14.7 per cent in 1911-12, and the highest was 17.9 per cent in 1908-9. The average extraction for the balance of Austria for the decade was 15.4 per cent and varied from 13 to 16.5 per cent. The sugar produced per acre in Bohemia increased from 3,983 pounds in 1903-4 to 4,693 in 1912-13, or an average for the decade of 3,990, as com-

pared with 3,454 pounds per acre for the remainder of Austria and 2,554 pounds for Hungary. During the decade 1903-4 to 1912-13 the Austrian factories employed annually an average of 73,856 people, or an average of 380 per factory. In 1912-13, 74,000 people were employed, of whom 59,000 were men and 15,000 were women. The annual production of sugar per employee was 14.94 tons, as against 22.97 per employee in the Hungarian factories.

HUNGARY.

BET SUGAR.

The area used for sugar beets in Hungary is confined chiefly to the valleys of the Danube and Tisza Rivers. The total area under cultivation during the 10 years 1903-1912 was 35,000,000 acres, of which 287,199, or 0.8 per cent, were used for sugar beets. The area under beets shows a large increase during the last 30 years. The area was 88,998 acres in 1883, 207,188 in 1893, 228,355 in 1902, and 449,910 in 1913. The average for the decade 1883-1892 was 120,757 acres, as against 203,790 for the decade 1893-1902 and 287,199 for the decade 1903-1912. The area under beets during the last decade has nearly doubled, increasing from 237,619 acres in 1903 to 449,910 in 1913. The beets produced have more than doubled, and increased from 2,328,759 tons in 1903 to 5,334,812 in 1912, or an average of 2,884,128 for the decade. The production of beets in Hungary shows a greater increase during the last 30 years than any other European country. The quantity produced was 813,408 tons in 1883, 1,715,459 in 1893, 2,164,397 in 1903, and 5,362,690 in 1913. Data for the sugar-beet industry during the decade 1903-4 to 1912-13 as compared with the preceding decade show remarkable improvement. The increase in area used for beets was 40.9 per cent, as against 61.1 per cent for beets produced. The beets used for sugar increased 52.6 per cent, while the sugar produced increased 100.5 per cent. The number of factories increased 15 per cent and the quantity of beets used for sugar per factory increased 32.7 per cent, compared with an increase of 74.4 per cent for sugar produced per factory.

The farm value of beets produced increased from \$6,980,786 in 1903 to \$22,979,500 in 1912, or an average of \$10,691,607 for the decade. The average price per ton ranged from \$3 in 1903 to \$4.30 in 1912, or an average of \$3.58 for the decade. The production of beets per acre increased from 9.80 tons in 1903 to 12.27 in 1912. The average for the decade was 9.86 tons per acre, as against 8.79 for the preceding decade, an increase of 12.2 per cent. The number of factories increased from 21 in 1903-4 to 28 in 1912-13, or an average of 23 for the decade, compared with 20 for the preceding decade. The quantity of beets used for sugar was more than doubled during

each of the last two decades. During the decade 1903-4 to 1912-13 the beets used increased from 2,026,993 tons to 4,540,432, or an average of 2,550,258 for the decade, compared with 1,671,293 for the preceding decade, which increased from 1,093,032 to 2,300,800 tons. During the decade 1903-4 to 1912-13, 88.4 per cent of the beets produced were used for sugar as compared with 93.3 per cent for the preceding decade. The production of sugar increased from 334,032 tons in 1903-4 to 651,587 in 1912-13, or an average of 405,049 for the decade, as against 201,985 for the decade 1893-94 to 1902-3, an increase of more than 100 per cent. The percentage of sugar extraction per weight of beets during the last 10 years increased from 13.9 per cent in 1902-3 to 15.6 in 1907-8, 16.5 in 1908-9, but decreased to 14 in 1912-13, and averaged 14.1 for the decade, as against 12.1 per cent for the preceding decade. The production of sugar per acre increased from 2,633 pounds in 1903-4 to 3,148 in 1912-13. The average for the decade was 2,554 pounds, as against 1,982 for the preceding decade, an increase of 28.9 per cent. The area of beets per factory increased from 10,190 acres during the decade 1893-94 to 1902-3 to 12,486 acres during the following decade, an increase of 22.5 per cent. The beets used per factory were 96,523 tons in 1903-4 and 162,158 in 1912-13, or an average for the decade of 110,881, as against 83,565 tons for the decade 1893-94 to 1902-3, an increase of 32.7 per cent. The production of sugar per factory increased from 15,906 tons in 1903-4 to 23,271 in 1912-13. The average for the decade was 17,610 tons, compared with 10,099 for the preceding decade, an increase of 74.4 per cent. The production of sugar per ton of beets averaged 242 pounds annually during the 10 years 1893-94 to 1902-3, and 318 pounds during the next 10 years, an increase of 31.4 per cent. The number of people employed in the Hungarian sugar factories increased from 14,422 in 1903-4 to 22,894 in 1912-13. The average for the decade was 17,635, of which 14,560 were men and 3,075 were women. The average production of sugar per employee during the last 10 years was 22.97 tons.

The Brussels Convention, which went into effect on September 1, 1903, exacts, on the part of each signatory Government, a scrupulous supervision of every refinery to insure that no untaxed sugar reaches the market. The following is a brief description of the control exercised by the Hungarian Government as reported by the United States consul stationed at Budapest:

Four weeks prior to the commencement of the manufacturing season each refinery is required to file with the Government a detailed plan of its factory, with a full description of its machinery and the marks or trade designations which will be used on its products. The refinery must be inclosed within a boundary wall 2 meters (6½ feet) high, with no direct communication to the interior of the factory. The plan must clearly indicate the exits from this

boundary wall. At every gate there is a watch room for the internal-revenue guard, and the factory is also required to provide living rooms for at least four guards, with an office and quarters for the revenue officer. The officer checks the production of the refinery and every shipment leaving it. These shipments may be made only between the hours of 6 a. m. and 7 p. m., in quantities not smaller than 500 kilograms (1,100 pounds), and from specially designated gates. The Government, through its fiscal officers located at the refineries, thus has complete control of sugar production and withdrawals from the factories for consumption.

RUSSIA.

BEET SUGAR.

The area devoted to the growing of sugar beets in European Russia extends practically over all of the southern half of that portion of the Empire. The principal area devoted to the crop is confined to six Provinces—Kiev, Podolia, Karkov, Kursk, Volhynia, and Warsaw. The area under beets increased nearly 40 per cent during the last 10 years, yet the increase in the area of cultivated land was such that the relation of beet area to the cultivated area was unchanged. The area under beets occupies approximately one-half of 1 per cent of the area under cultivation. The principal beet district is in the Provinces of Kiev and Podolia. These two Provinces contain nearly one-half of the sugar factories. The area of beets planted in Russia increased from 1,363,535 acres in 1903-4 to 1,896,410 in 1912-13, or an average for the decade of 1,517,887. The supply of beets is obtained from two sources, those grown on land cultivated or controlled by the factories and those grown by independent farmers. The area of beets planted by the factories was about one-third of the total area under this crop, and increased from 459,532 acres in 1903 to 582,825 in 1912. The area planted by independent farmers increased from 904,003 acres in 1903 to 1,313,585 in 1912. The area of beets harvested increased from 1,331,892 acres in 1903 to 1,847,313 in 1912, an average for the decade of 1,481,857, or 97.6 per cent of the area planted. The average area harvested during the decade ending with 1902-3 was 1,079,076 acres. The area harvested has more than doubled during the last 20 years, and increased from 825,644 acres in 1893-94 to 1,847,313 in 1912-13. Slightly better results were obtained from the area of beets grown by the factories than by the independent farmers. During the 10 years 1903-4 to 1912-13 the factories harvested 98.9 per cent of the area of beets planted, while the independent farmers harvested 97 per cent. The area of beets harvested per factory increased from 3,653 acres in 1893-94 to 6,437 in 1912-13.

The production of beets increased from 8,617,655 tons in 1903 to 14,940,490 in 1911, or an average of 10,386,550 tons for the 10 years ending with 1912. The average production of beets per acre for the

decade ending with 1912 was 6.9 tons, compared with 6.7 tons for the decade ending with 1902. The lowest yield for this 20-year period was 5.5 tons in 1900, and the highest was 8.9 in 1910. The quantity of beets used for sugar increased from 7,183,974 tons for the decade ending with 1902-3 to 10,206,556 tons for the decade ending with 1912-13, an increase of approximately 50 per cent. Of the beets produced during the decade ending with 1912-13, 98.3 per cent were used for sugar.

In most of the sugar-producing countries the tendency has been to reduce the number of factories, with a consequent increase in capacity. The opposite has been the case in Russia, except that a slight increase in capacity is shown. In 1913-14 there were 87 more factories in operation than in 1893-94 and 20 more than in 1903-4. In 1903-4 the average quantity of beets used per factory per day of 24 hours was 436 tons, which increased to 574 in 1911-12, but decreased to 524 in 1912-13. The annual production of sugar per factory increased from 4,202 tons in 1903-4 to 4,745 tons in 1912-13.

The daily average quantity of beets used by all factories varied from 121,908 tons in 1903-4 to 160,794 in 1911-12. The sugar content per weight of beets varied from 14.87 per cent in 1909-10 to 19.01 in 1907-8, or an average of 17.28 per cent for the decade ending with 1912-13. The percentage of sugar extracted, compared with the weight of the beets, varied from 11.35 per cent in 1905-6 to 14.87 in 1909-10, or an average of 13.30 for the decade ending with 1912-13. The loss¹ of sugar in the beets for the decade just mentioned was 3.98 per cent, equivalent to 393,496 tons of sugar, part of which was in the molasses. The production of sugar increased from an annual average of 892,236 tons for the decade ending with 1902-3 to 1,370,197 tons for the decade ending with 1912-13, an increase of 53.6 per cent compared with an increase of 42.1 per cent in the quantity of beets used. The annual production of sugar during the last 10 years increased from 1,147,268 tons in 1903-4 to 1,361,842 in 1912-13, or an increase of 18.7 per cent, while the beets used for sugar increased 35.9 per cent. The production of sugar in 1912-13 was nearly double the production in 1893-94, or an increase of 92.2 per cent, compared with an increase of 85.3 per cent in quantity of beets used for the same years. The production of sugar per ton of beets varied considerably, the lowest being 227 pounds in 1905-6 and the highest 297 pounds in 1909-10. The average for the 10 years ending with 1912-13 was 266 pounds, as against 247 pounds for the preceding decade. The annual production of molasses during the last 10 years averaged approximately 400,000 tons, or about 75 pounds per ton of

¹ Loss = difference between the sugar in the beets and the sugar actually extracted from them.

beets. The production of molasses stated in tons was about one-third that of sugar. The consumption of sugar shows a large increase, from 840,832 tons in 1903-4 to 1,490,989 in 1912-13. The per capita consumption of sugar increased from 12 pounds in 1903-4 to 17.4 pounds in 1912-13. The consumption of sugar during the last 10 years has more than kept pace with the population, increasing 77 per cent, while the population increased only 22 per cent. During this period the beet-sugar factories of Russia employed annually nearly 120,000 people. The employees in 1912-13 numbered 124,452, of which 101,531 were men, 18,060 were women, and the children under 15 years of age were—boys, 4,958; and girls, 803.

Russia was not a party to the Brussels Convention, but became a member on December 19, 1907, on condition that the Russian Government be authorized to maintain its interior legislation, which involved alleged indirect premiums. Also Russia agreed to having a limit placed upon its sugar exports. Thus the exports of sugar from Russia for the period September 1, 1909, to August 31, 1913, were fixed at 200,000 metric tons¹ (220,460 short tons). The same quantity was stated for the period 1913-1918, but in view of the scarcity of sugar on the European market and the increase in price, Russia was authorized to export an additional amount of 250,000 metric tons (275,575 short tons). Since becoming a member of the Brussels Convention the annual exports of sugar from Russia exceeded the amounts agreed upon in four different years. The exports for those four years were 329,000 tons in 1908, 226,000 in 1909, 500,000 in 1911, and 415,000 in 1912. The large exports in 1911-12 were made necessary on account of the drought in western Europe in 1911. During 1911 and 1912 the United Kingdom took nearly one-half of the sugar exported from Russia, amounting to 229,000 tons in 1911 and 161,000 tons in 1912. Exports to Germany for those two years were 43,000 and 15,000 tons, respectively. Turkey, Persia, and Finland have been the chief markets for Russian sugar. During the four years 1910-1913 the annual exports to those three countries were 89,330 tons to Persia, 41,529 to Turkey, and 49,977 to Finland. The total exports were 199,427 tons in 1904, which increased to 500,064 in 1911, but decreased to 162,419 in 1913. The average annual exports for the decade ending with 1913 were 241,202 tons, which was 17.6 per cent of the production. During the decade ending with 1902, 15.9 per cent of the sugar crop was exported, amounting to 141,531 tons. Comparing the data for the decade 1904-1913 with the preceding decade, the exports increased 46.7 per cent, while the production increased 53.6 per cent. The imports, though small, have increased during the decade 1904-1913, being for that period 3,051 tons annually, as against 375 tons for the preceding decade.

¹ Metric ton of 2,204.6 pounds.

During the last 10 years the imports fluctuated between 74 tons in 1909 and 11,392 tons in 1910. The quantity of sugar to be exported and the quantity to be placed on the home market are previously determined for each year by an imperially confirmed resolution of the Council of Ministers. The calculation is made on the basis of the consumption of the previous year and the probable annual increase. The manufacturers are compelled to keep a certain quantity as free reserve, and also a determined amount as inviolable reserve. The Government controls the price of sugar, and on the 1st of September, which is the beginning of the sugar year, a maximum price is fixed for the year. The year is divided into two parts, the first period being the first four months and the second period the last eight months. During the five years 1907-8 to 1911-12 a slightly higher price prevailed during the last period of the year.

FRANCE.

BEET SUGAR.

France ranks fourth among the countries of Europe in the growing of sugar beets, and for some recent years is surpassed by the United States. The total area under cultivation in 1892 was stated at 64,000,000 acres. In each of the years 1909, 1910, and 1911 it was stated at slightly more than 58,000,000 acres. The average area devoted to the growing of beets during the last twenty years has been about 600,000 acres, or about 1 per cent of the land under cultivation. The area since 1903 has decreased slightly as compared with the ten years preceding that date.

In 1882 the area of beets harvested was 587,001 acres. This area was reduced to 478,499 acres in 1885, and increased to 837,195 acres in 1901, which was the largest area in beets in the history of the industry. The area decreased in 1904 to 503,521, and increased with slight fluctuations to 566,539 acres in 1912. The yield per acre has been nearly uniform since 1886. The yield that year was 14.41 tons per acre, but decreased to 11.76 the following year, and the annual average yield since that date has been about 12 tons per acre. The year of largest production of beets was 1883, amounting to 9,969,414 tons, which decreased in 1887 to 5,648,083. The next year of large production was 1901, amounting to 9,939,948 tons, but decreased slightly more than one-half three years later, and in 1904 amounted to 4,922,157 tons. The following year, 1905, the production increased to 8,445,912 tons, but has been less than 7,000,000 tons since that time, except in 1912, when the production was 7,960,926 tons. The farm value of beets varied from \$21,348,000 in 1885 to \$44,874,000 in 1900. The average for the period 1885 to 1902 was about \$30,000,000. The farm value in 1903 was \$25,030,000, but fell to \$17,707,000 the follow-

ing year, the lowest during the period. This was due to both the low price of beets and the small production. The production in 1911 was lower, but the price was higher. The next year of large values was in 1912, amounting to \$39,794,000. The average annual value of beets during the period 1903 to 1913 was about \$25,000,000.

During the period 1885-1902 the average annual farm price per ton of beets was \$4.10; the average price paid by the factory for the same period was \$4.66. During the period 1903-1912 the average farm price per ton was \$4.40, while the factory price was \$4.33. The factory price during this period, as computed, was 7 cents below the farm price. During the latter period the factory price, as stated in the original, was lower than the farm price for the sugar campaigns of 1906-7, 1907-8, 1908-9, 1909-10, and 1911-12.

The number of sugar factories annually in operation has decreased more than one-half since 1882-83. The number that year was 497, and the number in 1912-13 was 213. During the 10 years preceding the Brussels Convention the average number of factories in operation annually was 340. During the 10 years following the convention the average number decreased to 255. The annual supply of beets used for sugar during the first period was 7,941,333 tons, and during the second period the quantity used was 6,507,075, a decrease of 1,434,000 tons annually. The annual production of refined sugar during the first period amounted to 847,337 tons, compared with 778,760 tons in the second period, or an annual decrease of 68,577 tons. The average annual production of sugar per factory during the first period was 2,492 tons, and during the second period 3,054 tons. The number of people employed in the sugar factories were 62,047 in the campaign year 1883-84, 49,971 in 1893-94, 42,632 in 1903-4, and 34,314 in 1912-13. The greater portion of the employees were men, ranging from 47,300 in 1883-84 to 31,764 in 1912-13. In 1883-84 there were 7,687 women and 7,060 children employed in the sugar factories. In 1912-13 the number of women employed had been reduced to 1,614 and the children to 936. The average number of people employed during the period 1893-94 to 1902-3 was 48,468, with an average production of sugar per employee of 17.48 tons. During the 10 years 1903-4 to 1912-13 the number of employees decreased to 37,782, but the production of sugar per employee increased to 20.61 tons.

The production of sugar per ton of beets in 1893-94 to 1902-3 averaged 235 pounds, which increased to 243 pounds during the 10 years 1903-4 to 1912-13. The per cent of sugar extracted per weight of beets increased slightly during the 20 years. The percentage of extraction was 11.8 per cent during the 10 years 1893-94 to 1902-3 and 12 per cent during the 10 years 1903-4 to 1912-13.

The beet pulp sold during the last 10 years was valued at an average of about 75 cents per ton, the range being from 70 to 81 cents. The average wages paid per day during the last 10 years were 82 cents for men, 45 cents for women, and 34 cents for children.

The coal used during the 10 years 1903-4 to 1912-13 averaged 781,944 tons annually, at an average price per ton of \$4.26.

Subsequent to 1886 the exports of sugar have exceeded the imports, except in the years 1911 and 1912, when the imports were in excess of the exports. The exports have shown a marked decline during the 10 years 1904-1913 compared with the preceding 10 years, 1894-1903. On the other hand, the imports have increased during the last 10 years as compared with the 10 years preceding. The average annual exports during the period 1894-1903 were 414,079 tons, compared with 262,763 tons during the period 1904-1913. The imports during 1894-1903 averaged 135,048 tons annually, and 146,814 tons during 1904-1913. The greater portion of the sugar exported was refined, and the most of the imports were raw sugar from French colonies.

The annual average consumption of sugar in France during the 10 years 1893-1902 was 480,967 tons, or 24.9 pounds per capita. The consumption during 1903-1912 was 662,438 tons annually, or 30.6 pounds per capita. The range of per capita consumption during the first 10 years was from 22.9 to 26.7 pounds and during the last 10 years from 30 to 38.6 pounds.

Statistics of beets grown for seed are available only for the Department of the Nord. The data given are for 1913 and 1914, and the area devoted to this purpose was 1,221 and 1,831 acres, respectively. The production of seed was 1,960,330 and 3,593,939 pounds, valued at 10.6 and 7.5 cents per pound, or a total of \$205,939 and \$267,434. The average yield per acre was 1,605 and 1,963 pounds, or an average value per acre of \$160.55 and \$146.06.

The sugar section of France is in the extreme northern part, composed chiefly of five Departments—Nord, Aisne, Oise, Somme, and Pas-de-Calais. These five Departments contain 180 of the 232 sugar factories, leaving only 52 for all of the other Departments.

ITALY.

BEET SUGAR.

The sugar-beet area of Italy is located in the northeastern part of the Kingdom, chiefly in two Provinces, Venetia and Emilia, bordering on the northern part of the Adriatic Sea. The Province of Venetia contained one-half of the area devoted to sugar beets, and Emilia about one-third. These two Provinces produced approximately 90 per cent of the beets during the six years 1909-1914. They also contain

26 of the 37 factories. The total area of Italy under cultivation aggregated 50,000,000 acres, of which less than three-tenths of 1 per cent was utilized for the growing of sugar beets, yet the production of sugar practically supplied the home demand in 1903 and subsequently. The area devoted to beets in 1906 was 93,784 acres, which increased to 152,709 acres in 1913. The production of beets increased from 1,128,118 tons in 1906 to 1,850,839 in 1910 and to 3,009,279 in 1913. The yield of beets per acre has been equal to and in some years has exceeded the larger and older beet-growing countries of Europe. The yield of 12.03 tons per acre in 1906 was increased to 14.92 in 1910 and to 19.70 in 1913. Data for beets used for sugar are not available prior to the campaign of 1906-7. The quantity used that year was 1,057,489 tons, which increased to 1,698,551 in 1910-11 and to 2,994,816 in 1913-14. The average annual production of beets for the five years 1909-1913 was 1,982,634 tons, of which 93.4 per cent, or 1,852,097 tons, were used for making sugar. The annual production of sugar during that period was 208,675 tons, or 11.27 per cent of the weight of the beets.

The beet-sugar factories increased from 34 in 1903-4 to 37 in 1913-14. The production of sugar has more than doubled during the last decade, amounting to 144,248 tons in 1903-4 and to 336,823 in 1913-14. The average annual production of sugar during the decade ending with 1912-13 was 149,009 tons, compared with 29,870 for the preceding decade, an increase of approximately 400 per cent. The production of sugar per acre of beets was increased from 2,500 pounds in 1906-7 to 4,400 pounds in 1913-14. The production of sugar per ton of beets used shows a much smaller increase, the production being 222 pounds in 1906-7 and 233 in 1912-13. The average length of the sugar campaign was given as about 75 days. During the sugar campaign the average production of sugar per factory was 3,665 tons in 1906-7, which increased to 9,103 tons in 1913-14. The exports of sugar from Italy have been practically nil and the imports since 1900 have been small. The largest quantity imported during any one year since 1900 was 26,166 tons in 1906, and the smallest quantity was 2,464 tons in 1903. The imports of sugar decreased from 89,259 tons in 1893 to 7,723 tons in 1912. The average annual imports for the decade ending with 1902 was 69,414 tons, as against 10,187 tons for the decade ending with 1912.

The per capita consumption of sugar in Italy as compared with other countries is among the smallest of any of the civilized nations. The official figures are shown only by five-year periods. Beginning with 1891-1895 the per capita consumption was 5.2 pounds, 8.6 pounds during 1906-1910, and 9.7 pounds during 1909-1913. The total consumption of sugar has increased from 88,566 tons annually for the

decade ending with 1902, as compared with 141,104 for the decade ending with 1912. During the latter decade the domestic sugar supplied more than 90 per cent of the consumption, compared with 30 per cent for the preceding decade. The small amount of sugar consumed is probably due to the high retail price of from 12 to 17 cents per pound. The import duty is from 8 to 10 cents per pound, and an excise or internal revenue tax of nearly equal amount is levied on all domestic sugars. The excise tax is not imposed on imported sugar, but an octroi or municipal tax of from 1 to 2 cents per pound is levied on all sugar shipped from one city to another by the city of final destination. Italy exports large quantities of candied fruits, but the sugar and sirups necessary for their preparation are imported in bond, on which no tax is levied, and shipped out again in the form of confectionery and sweetmeats.

BELGIUM.

BET SUGAR.

Sugar beets are grown in each of the nine Provinces of Belgium. The principal beet section is through the center from east to west and embraces the three Provinces of Brabant, Hainaut, and Liege. These Provinces contain about two-thirds of the area devoted to this crop. During the period 1903-4 to 1913-14 the total cultivated area of Belgium aggregated 4,400,000 acres, of which an annual average of 138,113 acres, or 3 per cent, was devoted to the growing of sugar beets. The year of smallest area, 109,470 acres, was followed by the year of largest area, 158,576 acres. During the period 1900 to 1913 there was not much increase in the area of beets. The annual average increased from 136,450 acres during the five years 1900-1904 to 144,164 acres during the five years 1909-1913. The production of beets shows a decrease from 1,856,454 tons to 1,770,361, and the yield of beets per acre also shows a decrease from 13.44 tons to 12.26 for the two periods, respectively. The production of beets per acre decreased from 15.31 tons in 1900 to 11.85 in 1913. The average for the 11 years ending with 1913 was 12.67 tons per acre.

The beet-sugar factories decreased from 113 in 1903-4 to 84 in 1913-14, while the production of sugar increased from 209,476 tons in 1903-4 to 249,395 in 1913-14. The smallest production of sugar for any year during the 11 years ending with 1913-14 was 184,706 tons in 1904-5, which was followed by the year of largest production, amounting to 345,905 tons. The annual average for the 11 years was 268,175 tons, or an average per factory of 2,765 tons. The beet factories in Belgium produce mostly raw sugar, which is sent to the refineries for further treatment. The refineries decreased from 26 in 1903-4 to 22 in 1912-13. The sugar extraction per weight of beets

increased from 13.03 per cent in 1903-4 to 16.25 per cent in 1913-14, with an average extraction for the period of 15.26 per cent. In 1912-13, 2,944 analyses of the sugar content of beets were made. In these tests the percentage of sugar per weight of beets ranged from 12.6 per cent to 19.6, with an average of 16.9. The per cent of sugar extraction for Belgium, while lower than that of Germany for the last 10 years, was higher for a portion of the period and showed a more gradual increase. The highest percentage of extraction for Belgium was 16.25 per cent in 1913-14, compared with 16.77 per cent for Germany in 1908-9. The production of sugar per ton of beets increased from 261 pounds in 1903-4 to 325 pounds in 1913-14, or an average of 300 pounds for the 11 years. The production of sugar per acre increased from 3,144 pounds in 1903-4 to 3,851 pounds in 1913-14, or an average of 3,796 pounds during the period.

The consumption of sugar has increased during the last 11 years from 77,164 tons in 1903-4 to 127,354 tons in 1913-14, or an average of 102,308 tons, which was 38 per cent of the production for the same period. The per capita consumption increased from 22.3 pounds to 33.3 pounds, or an annual average of 28.1 pounds for the 11 years. The imports have been small, averaging only 8,552 tons for the 11 years ending with 1913, as compared with 166,215 tons for exports. The greater part of the sugar produced has been exported, amounting to nearly two-thirds of the production. The sirup produced by the refineries averaged 3,051 tons and was valued at \$44,352.

NETHERLANDS.

BEET SUGAR.

The sugar-beet area of the Netherlands is located chiefly in the southwestern part, near the Belgian border. Approximately one-third of the area under beets was located in Zeeland and one-sixth in each of the Provinces of South Holland and North Brabant. The total area under cultivation increased from 1,505,000 acres in 1904 to 2,305,000 in 1913. Of this area slightly more than 5 per cent was devoted to the growing of sugar beets. The area under beets increased from 84,780 acres in 1904 to 160,180 acres in 1912, or an increase in proportion to the total area under cultivation of 1 per cent. The area of sugar beets for the decade ending with 1913 had an annual average of 125,403 acres, compared with 101,567 for the preceding decade, or an increase of nearly 24,000 acres. The average annual production of beets for the latter decade was 1,743,659 tons, compared with 1,403,546 for the preceding decade, or an increase of 340,000 tons. The yield of beets per acre during the decade ending with 1913 was lowest, 12.13 tons, in 1909, and highest, 16.06 tons, in 1911, or an annual average for the decade of 13.89 tons, compared with 13.58 for the preceding decade. The average annual value of

beets per ton increased from \$3.46 for the 10 years ending with 1903 to \$4.26 for the decade 1904-1913. The sugar content of beets was highest in 1908-9, 16.8 per cent of the weight of the beets, and lowest in 1905-6, 15.5 per cent. The factories increased from 28 in 1904-5 to 31 in 1913-14. The beets used for sugar increased from 965,533 tons in 1904-5 to 2,228,851 tons in 1912-13. The raw sugar produced increased from 150,974 tons in 1904-5 to 329,499 in 1912-13. The quality of the beets grown in the Netherlands is equal to any grown on the Continent. The sugar produced per ton of beets ranged from 273 to 313 pounds for 1904-5 and 1913-14, respectively. The production of sugar per acre ranged from 3,500 to more than 4,000 pounds. The production of sugar per factory in 1904-5 was 5,392 tons, which was doubled in 1912-13, amounting to 10,983 tons. The beet pulp sold was valued at 87 cents per ton in 1904-5, and \$1 per ton in 1912-13. The sugar consumed has been about one-third of the production. The average annual per capita consumption during the five years 1902-1906 was 29.85 pounds, compared with 32.52 pounds for the five years 1907-1911. For a number of years the Netherlands has been a large exporter of sugar, and during the decade ending with 1913 the average annual exports were 181,317 tons, or approximately three-fourths of the production.

Compared with other crops in 1912, sugar beets exceeded the area devoted to wheat and barley, but were exceeded in area by rye, oats, and potatoes. The farm value of sugar beets produced that year was \$11,372,000, compared with \$26,000,000 for potatoes, \$22,000,000 for rye, and \$13,000,000 for oats. The average value per acre was sugar beets \$71, potatoes \$61, wheat \$57, barley \$53, rye and oats each \$40.

SPAIN.

BET SUGAR.

Spain is the only country in Europe that produces both beet and cane sugar in commercial quantities. Its beet-sugar industry has been developed within the last quarter of a century and in 1912 occupied 12 times the area devoted to cane and the production of beet sugar was more than 10 times that of cane. The soil and climatic conditions are better adapted to the growing of sugar beets and the beets are grown in nearly all parts of the kingdom, while the growing of cane is confined to a restricted area. Sugar beets are grown in 19 of the 30 Provinces, while cane is grown only in 3 Provinces. Most of the beets have, in recent years, been grown in the north-central Provinces, yet the Province of Granada, in the extreme southern part, that was second in production of beets and beet sugar in 1912-13, was also second in the production of cane and cane sugar. This Province contained one-third (or 15) of the beet-sugar factories

in 1912 and 1913 and nearly one-half (or 15) of the cane-sugar factories. The area under cultivation in Spain in 1911 was 41,000,000 acres, of which approximately three-tenths of 1 per cent was used for sugar beets. The statistics for production of beets are available for only one year, 1912, and was 1,452,991 tons, of which 1,302,871, or 89.7 per cent, was used for sugar. The yield of beets per acre that year was 9.9 tons and was sold at a price varying from \$5.70 to \$6.70 per ton, or a total farm value exceeding \$9,000,000.

The number of beet-sugar factories has decreased from 55 in 1905-6 to 45 in 1913-14, of which 25 were idle in 1905-6 and 19 in 1913-14. The beet-sugar industry in Spain and the United States was placed on a paying basis about the same time and the growth of the industry has made rapid progress in both countries, but much more rapid in the United States than in Spain. The production of beet sugar during the five years 1909-1913 as compared with 1899-1903 shows a gain of 77.3 per cent for Spain and 320.7 per cent for the United States. The beets used for sugar in Spain increased from 11,790 tons in 1896-97 to 1,478,114 tons in 1913-14, and the sugar produced increased from 920 tons to 186,680 for the same years. The average annual quantity of beets used for sugar during the decade 1903-4 to 1912-13 was 865,070 tons, with an average production of 102,777 tons of sugar. The quantity used for sugar varied from 929,787 tons in 1903-4 to 1,302,871 in 1912-13, and the production of sugar for the same years varied from 104,947 to 171,839 tons. The percentage of sugar extraction per weight of beets increased from 11.28 per cent in 1903-4 to 12.92 in 1909-10, but decreased to 11.33 in 1912-13, or an average for the decade of 11.67 per cent. Comparing the 5 sugar campaigns 1899-1900 to 1903-4 with the campaigns of 1909-10 to 1913-1914, an important increase is shown in sugar extraction. The sugar produced during the latter period increased 77.3 per cent over the former period, as against 36.7 per cent for beets used for sugar. The average per cent of extraction during the first period was 9.73 and 11.94 during the second period, an increase of 22.7 per cent. The average production of sugar per ton of beets during the five years 1899-1900 to 1903-4 was 196 pounds, as against 254 pounds for the five years 1909-10 to 1913-14, an increase of 29.6 per cent. During the campaign 1913-14 the factory producing the largest quantity of sugar was located in Zaragoza. This factory used 130,528 tons of beets and produced 18,419 tons of sugar. The average daily consumption of beets by this factory was 1,346 tons, from which 190 tons of sugar were produced. The harvesting of beets and manufacture of sugar in Spain begins in August and ends the following February, a season of approximately 200 days. The average length of the sugar campaign for all factories was 72 days in 1912-13 and 79 in 1913-14.

CANE SUGAR.

The cane-sugar industry in Spain is an old one and has been localized for a number of years in the three Provinces of Almeria, Granada, and Malaga. The growing of cane is confined to a small area, and occupied 11,666 acres in 1910, 9,983 in 1911, 9,844 in 1912, and 4,581 in 1913. The production of cane decreased from 258,137 tons in 1910 to 167,092 in 1911, 153,707 in 1912, and 79,719 in 1913. The average production of cane per acre was 21.9 tons in 1910, 16.5 in 1911, 15.6 in 1912, and 17.4 in 1913. The cane-sugar industry has been less profitable than the beet-sugar industry, and the quantity of cane used for sugar during the last 15 years has decreased, while the quantity of beets used has increased. The cane crushed during the three years 1899-1900 to 1902-3 averaged 320,504 tons, compared with 133,506 tons for the three years 1911-12 to 1913-14. The production of sugar decreased from 28,962 tons to 13,566 tons, respectively, for the two periods just mentioned. The production of sugar per ton of cane for these two periods increased from 178 pounds in the first period to 202 pounds in the second period. During the decade 1903-4 to 1912-13 the cane used decreased from 287,735 tons in 1903-4 to 153,707 tons in 1912-13, or an average of 226,394 for the decade. The production of sugar decreased from 24,444 tons in 1903-4 to 14,585 in 1912-13, or an average for the decade of 20,783 tons. The average production of sugar per ton of cane for the decade was 184 pounds, and exceeded 200 pounds for the years 1907-8, 1909-10, and 1911-12. The percentage of sugar extracted per weight of cane increased from 8.49 per cent in 1903-4 to 9.48 per cent in 1912-13, or an average of 9.43 per cent for the decade ending with 1912-13. The season for making cane sugar extends over a period of approximately 200 days, beginning in December and ending in June. However, the average days in actual operation for all factories was 56 in 1912-13 and 49 in 1913-14.

During the decade 1903-4 to 1913-14 there was an average of 22 cane-sugar factories of modern equipment and 13 trapiches, or small mills, using the open-kettle process for making sugar. Of the 22 factories, an average of 17 were in operation and 5 were idle. Of the 13 trapiches in existence, 9 were in operation and 4 were idle. The beet factories made a poorer showing than the cane factories, for the number decreased from 55 in 1903-4 to 45 in 1913-14, or an average of 50 for the decade. Of the 50 factories, only 32, or 64 per cent, were in operation, while 18, or 36 per cent, were idle. The sugar industry in Spain for the last 15 years has been in a more or less unsatisfactory condition owing to overproduction and the low prices as compared with the cost of production. The loss of the Spanish colonies in 1898 checked the imports of sugar and stimulated domestic

production. The outlook for the home industry was promising and capital was invested in new factories, which increased from 26 in 1898 to 48 in 1901, 79 in 1903, and 88 in 1904. The increase in number of factories resulted in such a large overproduction of sugar that in 1903 a company was formed known as the "Sociedad Azucarera Espanola." This company operated 60 per cent of the sugar factories and was organized for the purpose of limiting the output of sugar and maintaining prices above cost of production. This company included 11 of the cane and 42 of the beet factories in 1904, a total of 53. The independent factories were cane 10, trapiches 12, and beet 13, a total of 35, or 40 per cent of the total number of factories. The associated factories gradually decreased to 37 in 1913, while the independent factories increased to 42, or 53 per cent of all factories. The organization of this sugar association did not entirely relieve the situation. The rivalry that sprang up between the two classes of factories resulted in an annual overproduction, with a consequent lowering of prices, and the stock of 89,580 tons of sugar on hand on December 31, 1904, was increased to 158,310 tons on December 31, 1914. The independent factories had a higher percentage of sugar extraction than the associated factories during the decade ending with 1912-13. For this period the average extraction per weight of cane or beets for the independent factories was 9.23 per cent for cane, and 12 per cent for beet, as against 9.11 for cane and 11.57 for beets for the associated factories.

SUGAR SUPPLY.

Prior to 1900 the principal source of the Spanish sugar supply was Spain's colonial possessions of Cuba, Porto Rico, and the Philippine Islands. Approximately two-thirds came from Cuba, very little, amounting to less than 2,000 tons, coming from foreign countries. The annual imports from all sources for the decade 1883-1892 were 62,660 tons, of which 39,505 tons came from Cuba. During the next decade, 1893-1902, the annual imports of sugar decreased to 21,977 tons, of which 9,991 tons came from Cuba. During the decade 1903-12 the annual imports decreased to 49 tons. The imports began to decrease in 1893, when the sugar-beet industry began to develop, and as this industry expanded the imports decreased. Prior to 1893 the colonies were the principal source of the sugar supply; for the next 10 years the domestic production slightly exceeded the imports, and from 1903 to 1912 practically no sugar was imported. The exports have been in negligible quantities, amounting to an average of only 59 tons for the decade 1893-1902, as against 711 tons for the decade 1903-1912. The exports in 1913 exceeded all previous years, amounting to 5,736 tons. The consumption of sugar in Spain in-

creased from 97,266 tons in 1903-4 to 147,204 tons in 1912-13, or an average of 119,780 tons for the decade. The per capita consumption during this period was approximately 12 pounds. The consumption of sugar during the five years 1909-1913 as compared with the five years 1900-1904 shows an increase of 41.3 per cent, as against an increase of 49.6 per cent in production for the same period.

DENMARK.

BEET SUGAR.

The area of land in Denmark devoted to the growing of sugar beets is located chiefly in the islands southeast of the mainland. These islands have annually produced about 97 per cent of the sugar beets, and contain also all of the factories. The total area under cultivation in 1907 was 6,376,000 acres, which increased slightly to 6,644,000 acres in 1912. Of this area, sugar beets occupied 0.6 per cent, or 39,568 acres, in 1907, and 1.2 per cent, or 79,986 acres, in 1912. While the area devoted to the growing of beets has increased 100 per cent since 1907, the production of beets has increased 200 per cent since 1904. The production that year was 393,011 tons, which increased to 1,159,369 in 1912. The annual average for the decade ending with 1913 was 671,540 tons. The production of beets per acre increased from 11.32 tons in 1907 to 14.49 in 1912. The area and farm value of sugar beets, while much less than that of other crops, has shown a greater increase than any of the other principal crops. The value of beets increased more than 122 per cent during the decade ending with 1912, while the value of all crops, including beets, increased only 64 per cent. The beets were valued at \$1,569,000 in 1903 and \$3,484,000 in 1912, while the value of all crops for the two years, respectively, was \$112,273,000 and \$184,170,000. The value of wheat decreased from \$3,351,000 in 1903 to \$3,296,000 in 1912. The increases in other crops for the two years, respectively, were rye \$12,503,000 to \$14,954,000, barley \$14,782,000 to \$19,564,000, oats \$19,014,000 to \$23,638,000, potatoes \$3,994,000 to \$6,110,000. The farm value of beets per ton ranged from \$3.16 in 1910 to \$4.42 the following year.

The beet-sugar factories increased from 7 to 9 during the decade 1904-1913. Two new factories were recently erected, one in 1910, the other in 1912. The output of sugar varied from 48,639 tons in 1904 to 179,002 in 1913, or an annual average for the decade of 95,983 tons. The production in 1914 decreased to 167,803 tons. The production of sugar per acre increased from 2,934 tons in 1907 to 3,712 tons in 1912, and the production per factory increased from 6,948 tons in 1904 to 19,889 tons in 1913. The sugar extraction per ton of beets increased from 248 pounds in 1904 to 349 pounds in

1913, an increase of 40 per cent. Denmark has never produced enough sugar to supply domestic requirements but is rapidly approaching that condition. During the five-year period 1876-1880 only 4 per cent of the sugar consumed was of domestic origin; this was increased to 63 per cent during the five years 1896-1900 and to 90 per cent in 1914. The consumption of domestic sugar increased from 1,080 tons in 1876-1880 to 116,193 tons in 1914, while the total consumption increased from 28,792 tons to 129,807 for the same period. The per capita consumption increased from 29.72 pounds in 1876-1880 to 90.81 pounds in 1914, an increase of 200 per cent. The average annual consumption of sugar during the decade 1904-1913 was 106,375 tons, or 110.8 per cent of the production; the imports averaged 27,959 tons, or 29.1 per cent of the production. The imports decreased from 41,501 tons in 1904 to 13,444 tons in 1913, while the exports increased from 13 tons to 50,534 for the same period.

SWEDEN.

BEET SUGAR.

The territory of Sweden used for growing sugar beets is in the extreme southern part, chiefly in Provinces along the coast. The Province of Malmöhus, which exceeded all other Provinces combined in production of beets in 1913 and 1914, produced 579,153 tons of beets, or 62.2 per cent of the total, in 1913, and 647,178 tons of beets, or 66.9 per cent, in 1914. The Province of second importance in the production of beets for these two years was Kristianstad, and the third in importance was the island of Gottland. The total area under cultivation in Sweden in 1911 was 9,200,000 acres, of which 71,790 acres, or 0.8 per cent, was used for sugar beets. The area used for beets decreased from 79,257 acres in 1908 to 66,900 in 1912, but increased to 79,700 in 1914. The annual average for the five years 1906-1910 was 80,723 acres. The production of beets has more than doubled during the last 20 years, and increased from 453,245 tons in 1893 to 924,164 in 1901, but decreased to 670,120 the following year and increased to 933,067 in 1912 and to 966,998 in 1914. The average production of beets for the five years 1891-1895 was 466,445 tons, which increased to 749,973 for 1896-1900, 768,995 for 1901-1905, and 1,053,947 for 1906-1910. The average yield per acre increased from 13.04 tons in 1908 to 14.83 in 1911, but decreased to 13.95 in 1912 and to 12.13 in 1914. The annual farm value of the beet crop increased from \$2,037,000 for the five years 1891-1895 to \$3,725,000 for 1901-1905 and to \$6,378,000 for 1906-1910. The value in 1909 was \$6,325,000, which decreased to \$5,241,000 in 1914. The average price paid for beets in 1913 was \$5.59, which decreased to \$5.42 per ton in 1914.

The number of beet-sugar factories in Sweden increased from 13 for the five years 1891-1895 to 19 for 1896-1900, to 21 for 1901-1905, to 23 for 1906-1910, and to 24 for the five years ending with 1913. The beets used for sugar increased from 458,261 tons for the five years 1891-1895 to 790,409 for 1896-1900 and to 1,036,929 for 1906-1910. The annual production of sugar by five-year periods increased from 51,794 tons in 1891-1895 to 112,750 in 1901-1905 and to 156,688 in 1906-1910. The production of sugar per ton of beets increased from 212 pounds for the five years 1891-1895 to 302 for 1906-1910 and to 316 for 1912-13. The sugar extraction per weight of beets shows a gradual increase from 10.93 per cent for the five years 1891-1895 to 14.94 for 1906-1910 and to 15.59 for 1912-13, an increase during the latter year of 42.5 per cent over the five years 1891-1895.

The five years 1906-1910 compared with the five years 1891-1895 show an increase of 126 per cent in both beets produced and beets used for sugar. For these two periods the production of sugar increased 202.5 per cent and the number of factories increased 76.9 per cent. During each of these periods more than 98 per cent of the beets produced were used for sugar. For these two periods the production of molasses in the beet factories increased from 12,896 tons to 13,492 tons. The sugar produced per acre averaged 3,882 pounds for the five years 1906-1910, which increased to 4,349 pounds for the year 1912-13. From 1906-7 to 1912-13 there were 10 sugar refineries in operation which refined both domestic and imported raw sugar. During the five years 1906-7 to 1910-11 these refineries used 141,806 tons of raw sugar, from which was obtained 133,376 tons of refined sugar, 1,268 tons of sirup, and 7,390 tons of molasses. The per capita consumption of sugar was 30.1 pounds for the five years 1891-1895 and 57.8 pounds for the five years 1906-1910, an increase of 92 per cent. The exports of sugar decreased from 300 tons in 1911 to 1 ton in 1912, but increased to 12,646 tons in 1914. The imports of sugar were 47 tons in 1911, which decreased to 16 tons in 1914.

ROUMANIA.

BEET SUGAR.

The sugar-beet area of Roumania lies chiefly in the northern part, in the Province of Moldavia, and forms a connecting link between the sugar-beet districts of Hungary on the west and Russia on the east. In 1907-8 and subsequently there were five sugar factories in operation in Roumania, of which four were in Moldavia and one in Wallachia, near Bucharest. The Province of Moldavia produced 84.89 per cent of the beets in 1909, of which 51.93 were produced in the valleys of the Sereth and Pruth Rivers and 32.96 in the plains of the Carpathian Mountains. The annual area under cultivation dur-

ing the decade 1903-1912 was 14,800,000 acres, of which 27,577 acres, or 0.2 per cent, were under beets. The area used for beets increased from 22,039 acres in 1903 to 36,534 in 1913, or an average for the decade 1903-1912 of 27,577 acres. The five-year period 1908-1912 compared with the five years 1903-1907 shows an increase of 42.7 per cent in area of beets, as against an increase of 63.1 per cent in quantity of beets produced. The production of beets was 159,935 tons in 1903, which increased to 311,250 in 1912, or an average of 247,976 for the decade. The yield of beets per acre increased from 7.24 tons in 1903 to 10.32 in 1909, but decreased to 9.68 in 1912, and the average for the decade was 8.56 tons. During the eleven years 1903-1913 the yield of beets per acre was lowest in 1913 and amounted to only 6.79 tons. The area that year was 36,534 acres, the largest of the entire period, but the production of beets, 247,976 tons, was the lowest since 1908. The farm value of beets was \$805,000 in 1907, which increased to double that amount, \$1,665,000, in 1909, but decreased to \$1,303,000 in 1913. The value of the beets per ton increased from \$4.38 in 1907 to \$5.25 in 1913. The average value of the beet crop per acre was \$36.13 in 1908, \$50.60 in 1910, \$48.30 in 1913, and \$35.65 in 1914. The beets produced formed 0.44 per cent of the value of all agricultural products in 1908, 0.66 per cent in 1910, 0.47 per cent in 1911, and 0.53 per cent in 1914.

The production of sugar in Roumania began in the early eighties. Figures for 1886 show a production of only 671 tons for that year. Ten years later the quantity produced was 1,884 tons. In 1899-1900 the production amounted to 14,713 tons, which increased to more than twice that amount in 1902-3, again doubled in 1910-11, amounting to 55,118 tons, but a decline to 35,887 tons is shown for 1911-12. The output of sugar for the five-year period 1899-1900 to 1903-4 was 29,752 tons, as against 39,071 tons for the five years 1907-8 to 1911-12, an increase of 31.3 per cent. The figures of production as just stated do not represent the actual production for each year, as the stock of sugar on hand at the close of the sugar year is included in the production of the following year.

The consumption of sugar during the 13 years 1899-1900 to 1911-12 has nearly doubled and amounted to two-thirds of the production. The consumption in 1898-99 was 23,531 tons; in 1906-7, 28,992 tons; in 1912-13, 38,525 tons. The consumption during the five years 1899-1900 to 1903-4 was 19,083 tons, as against 31,916 tons for the five years 1907-8 to 1911-12, an increase of 67.2 per cent, while the production for the same period increased only 31.3 per cent. The domestic production of sugar in Roumania has been about equal to the domestic requirements. Small quantities of sugar have been exported, but almost an equal amount has been imported. The annual exports for the decade 1903-4 to 1912-13 were 2,177 tons, while the

imports amounted to 308 tons. The exports varied from 4 tons in 1908-9 to 6,359 in 1910-11, and the imports varied from 175 tons in 1907-8 to 887 in 1912-13.

SWITZERLAND.

BET SUGAR.

The area used for growing sugar beets in Switzerland is located in the western part, mostly in the canton of Berne, but for some years beets were grown also in the canton of Vaud. With the exception of the four years 1893 to 1896 the data for production and value of beets are for the canton of Berne. In 1904 the area under beets in Berne was 1,148 acres, which decreased to 1,025 acres in 1910. The annual production of beets was 7,656 tons for the decade 1893-1902, and 11,930 tons for the decade 1903-1912, an increase of 58.9 per cent. The production of beets in Vaud was 1,958 tons in 1893, 6,656 in 1894, and 11 in 1896. For Berne the production of beets increased from 37 tons in 1895 to 20,221 in 1901, decreased to 16,130 in 1905, and increased to 20,772 in 1913. The value of beets produced in Vaud was \$8,570 in 1893, \$30,301 in 1894, and \$40 in 1896. The beets produced in Berne were valued at \$253 in 1895, \$74,350 in 1901, \$63,133 in 1905, and \$79,531 in 1913. The annual value of beets produced was \$29,300 for the decade 1893-1902 and \$49,857 for the following decade, an increase of 70.1 per cent, as against 58.9 per cent for production of beets. The annual value of beets per ton was \$3.83 for the decade 1893-1902, as compared with \$4.18 for the decade 1903-1912. The yield of beets per acre was 12.96 tons in 1904, with a value per acre of \$51.94. In 1910 the yield was 11.04 tons, which was valued at \$47.91.

The only sugar factory in Switzerland is located at Aarberg, in the canton of Berne, and produces only refined sugar. The output of this factory averaged 3,631 tons for the six years 1906-7 to 1911-12. The output of sugar varied from 4,012 tons in 1906-7 to 4,032 in 1908-9 and 2,976 in 1910-11. The factory was destroyed by fire in January, 1912, but was rebuilt and resumed operations in 1913-14. This factory employs 400 people and the wages paid monthly approximate \$10,000.

Very little if any sugar has been exported from Switzerland, but the imports have increased from 87,710 tons in 1904 to 134,145 in 1912, decreased to 129,257 in 1913, or an average of 107,203 for the decade. The imports of sugar for the five years 1906-1910 were 101,897 tons, compared with 89,915 for the five years 1901-1905, an increase of 13.3 per cent.

The per capita consumption of sugar in Switzerland is larger than for most of the other European countries and amounted to 61.5

pounds in 1910. The total consumption of sugar for that year was 115,529 tons. A large quantity of the sugar consumed in Switzerland is used in the confectionery, condensed milk, and chocolate industries, and is afterwards exported. The exports of these products in 1913 were 44,708 tons for condensed milk, 18,538 for chocolate, and 1,658 for confectionery.

BRITISH INDIA.

CANE SUGAR.

The area of British India used for sugar cane is in the northern part, in the valleys of the Ganges and Indus Rivers. The United Provinces of Agra and Oudh contain one-half of the area under cane and produce one-half of the sugar. The Provinces of Punjab, Bihar, and Bengal contain the greater portion of the remainder of the area under cane. Cane is also grown in the Provinces of Bombay in the west and Madras in the south. The sugar-cane areas of India are like those of the United States in the sense that they lie mostly outside of the tropics and are subject to frost. Sugar cane is a tropical plant and thrives best in a uniformly warm climate where there is an abundance of water supply and in an alluvial soil retentive of moisture. These conditions exist in the valleys of the Ganges and Indus Rivers, with their numerous irrigation canals. In the south, where climatic conditions are better suited to this crop, the other physical conditions are less favorable. In this way the sugar-cane cultivation of India has been driven from the tropics and thrust northward close to the limit of cane cultivation. These conditions, together with the backward methods of cultivation and manufacture of sugar, are chiefly responsible for the low yield of sugar per acre in India. The estimated yield of cane per acre on the best land is 20 tons, but the primitive methods of extracting the sugar leave about one-half of the sugar in the cane. The fields are widely scattered and so far apart that the cost of transportation from field to factory forbids the large central sugar factory as used in other sugar-cane countries.

The total area under cultivation in India during the decade 1903-4 to 1912-13 was 257,000,000 acres, of which 2,279,859, or a little less than 1 per cent, was used for cane. Nearly one year is required for cane to mature in India. It is planted in February, March, and April and harvested in December and January. The average yield of sugar per acre has been about 1 ton, but slightly exceeded that figure in recent years, and amounted to 2,290 pounds in 1912-13 and to 2,011 in 1913-14. The cane grown in the United Provinces yields from 1,500 to 3,200 pounds of raw sugar (guñ) per acre. The yield of sugar per acre varies considerably in the other Province, from

1,904 pounds (17 hundredweight) for Assam, 2,464 pounds (22 hundredweight) for Bengal, 2,688 pounds (24 hundredweight) for Eastern Bengal, to 5,040 pounds (45 hundredweight) for Madras. The total production of raw sugar for all Provinces increased from 2,096,624 tons in 1903-4 to 2,893,632 in 1912-13, decreased to 2,534,112 in 1913-14 and increased to 2,952,320 in 1915-16. The average for the decade 1903-4 to 1912-13 was 2,382,371 tons.

There are only about 20 modern factories in India and they are small. This class of factory increased from 20 in 1903-4 to 26 in 1912-13, or an average of 23 for the decade. Most of these factories are refineries, in which raw sugar prepared by the natives (rab or gur) is purified. The number of employees for the factories given varied from 4,018 in 1903-4 to 7,870 in 1912-13, or an average of 5,363 for the decade. The average number of employees per factory for the decade was 233.

The production of sugar in British India, while in excess of other countries, has fallen short of domestic requirements, as an average of 604,193 tons annually were imported during the 10 years 1904-1913. The imports increased from 388,023 tons in 1904 to 961,005 in 1913, and decreased to 605,884 in 1914. The exports increased from 25,409 tons in 1904 to 40,227 in 1912, but decreased to 21,604 in 1914. The annual average for the decade 1904-1913 was 25,839 tons for domestic exports and 177,755 for foreign exports, or a total of 203,594 tons exported. The consumption of sugar for the decade 1904-1913 was 2,585,965 tons, or an average per capita consumption of 16.7 pounds. Large quantities of cane are eaten raw as a delicacy by the natives, and for this purpose a special variety is grown, containing less sugar but having a softer fiber. The sugar consumed by the natives is raw sugar (gur) and is prepared for market by being poured into small holes scooped out in the ground or molded into balls or cakes by hand. Very little refined sugar is used.

JAVA, DUTCH EAST INDIES.

CANE SUGAR.

The growing of sugar cane in the Dutch East Indies is practically confined to the Island of Java. The total area under cultivation in Java and Madura in 1911 was 12,800,000 acres, of which 405,000 acres, or 3 per cent, was in sugar cane. Two other crops exceeded the sugar cane in area. They were rice, 5,883,000 acres, and tobacco, 421,000 acres. Cane is grown in all parts of Java, but the four Provinces of Soerabaja, Pasoeroean, Kediri, and Djokjakarta produced 60 per cent of the sugar in 1913. These Provinces also contained 107 of the 191 factories in operation that year. The harvest

season begins in May and ends in November. Cane for the sugar factories in Java is obtained from two sources, cane grown on land owned or controlled by the factory owners and cane grown by the natives. Statistics of area under cane grown by the natives are not available, but the cane purchased from the natives during the last 10 years slightly exceeded one-third the amount of factory-grown cane used for sugar. The area of cane cultivated by the factories increased from 255,905 acres in 1903-4 to 340,739 in 1912-13, or an average of 285,372 for the decade. The factory-grown cane used for sugar increased from 10,439,140 tons in 1903-4 to 15,370,765 in 1912-13, or an average of 12,459,284 for the decade. The cane purchased from the natives increased during the same period from 222,730 tons to 507,669, with an average of 454,150 for the decade. The sugar produced from factory-grown cane increased from 1,141,508 tons in 1903-4 to 1,527,584 in 1912-13, or an average for the decade of 1,296,437 tons. The sugar obtained from cane purchased from the natives during the same period increased from 18,358 tons to 50,748, or an average of 36,890 for the decade. During the last 10 years a decrease is shown in the proportion of sugar obtained from factory-grown cane compared with the purchased cane. Comparing the five-year period 1908-9 to 1912-13 with the five years 1903-4 to 1907-8, the factory cane used for sugar increased 28.1 per cent, while the production of sugar increased only 25.3 per cent. During the same periods the quantity of purchased cane used for sugar increased 17.3 per cent, but the sugar produced increased 41.0 per cent. The quantity of cane crushed per acre was 40.79 tons in 1903-4 and 45.11 tons in 1912-13, with an average of 43.66 tons for the decade. The highest for the decade was 46.43 tons in 1910-11, which exceeds all other countries; however, this is hardly a fair comparison, for the figures represent only the area cultivated or controlled by the factories and exclude the area cultivated by the natives. The yield per acre for the Territory of Hawaii in 1913 was 43 tons, which probably exceeds Java if the entire cane area of the latter island be considered.

The number of sugar factories in operation in 1903-4 was 184, which increased to 191 in 1912-13, or an average of 184 for the decade. The factories produced 1,159,866 tons of sugar in 1903-4, which increased to 1,578,332 in 1912-13, or an average of 1,333,326 for the decade. The production of sugar per factory increased from 6,304 tons in 1903-4 to 8,264 in 1912-13, or an average of 7,246 for the decade. The Hawaiian factories each produced an average of 11,900 tons of sugar in 1912, 10,900 in 1913, and 13,300 in 1914. The production of sugar per acre in Java from factory-grown cane increased from 8,917 pounds in 1903-4 to 8,966 in 1912-13. The highest yield per acre for the decade was 9,842 pounds in 1910-11, with an average of

9,086 pounds for the decade, compared with the Hawaiian production of 8,253 pounds per acre in 1898-99 and 11,400 in 1914-15. The extraction of sugar per ton of cane was much larger from factory-grown cane than from that purchased from the natives. The sugar extraction from a ton of factory-grown cane decreased from 219 pounds in 1903-4 to 199 pounds in 1912-13, or an average of 208 pounds for the decade, while the extraction from purchased cane increased from 165 pounds per ton of cane in 1903-4 to 200 in 1912-13, or an average of 162 pounds for the decade. This is considerably less than the extraction shown for Hawaii, which ranged from 230 pounds in 1898-99 to 250 pounds in 1913-14. The percentage of sugar extraction per weight of cane was 10.93 per cent in 1903-4, and 9.94 in 1912-13, with an average of 10.41 per cent for the decade. The extraction from the purchased cane ranged from 5.50 per cent in 1905-6 to 10 in 1912-13, the average for the decade being 8.12 per cent.

The sugar industry of Java has made remarkable progress during the last 30 years. The production of sugar increased from 360,723 tons in 1883 to 1,578,332 tons in 1913, an increase of nearly 400 per cent. The average annual production of sugar during the decade 1883-1892 was 435,066 tons, as against 722,174 tons for the decade 1893-1902, an increase of 66 per cent. The production during the decade 1904-1913 was 1,333,326 tons, which was an increase of 84.6 per cent over the preceding decade and an increase of 206.5 per cent over the decade 1883-1892. The average annual yield of cane per acre increased from 35.32 tons for the decade 1894-1903 and to 43.66 tons for the decade 1904-1913, an increase of 23.6 per cent. The average production of sugar per acre for these two decades, respectively, was 7,447 and 9,086 tons, an increase of 22 per cent.

The exports of sugar from Java in 1904 were 1,159,110 tons, which increased to 1,621,950 in 1913, or an average of 1,341,605 for the decade, an increase compared with the preceding decade of 81.4 per cent. During the decade 1893-1902, 97.3 per cent of the sugar produced was exported, as against 95.7 per cent for the decade 1903-1912. China, United States, United Kingdom, and British India have been the best markets for Java sugar. During the decade 1893-1902 approximately two-thirds of the sugar exported was consigned to the United States, United Kingdom, and China. During the decade 1903-1912 the exports to the United States and United Kingdom decreased, while the exports to China and British India increased to approximately one-half of the total exports. The imports have been small, ranging from 4,574 tons in 1907 to 3,728 in 1913. The consumption of raw sugar in Java increased from 13,268 tons in 1905 to 24,952 in 1913, or an average of 23,717 for the decade 1904-1913.

MAURITIUS.**CANE SUGAR.**

During the last ten years the annual area used for cane and the production of sugar in Mauritius has exceeded that of any other British possession except British India. The area used for sugar cane in that island increased from 63,570 acres in 1893-94 to 83,935 in 1901-2, to 96,686 in 1908-9, and to 160,013 in 1913-14. The annual area under cane during the decade 1893-1902 was 74,383 acres, which increased to 109,964 acres during the decade 1903-1912, an increase of 47.8 per cent. The production of sugar in Mauritius increased from 78,993 tons in 1893-4 to 171,209 in 1902-3 and to 275,250 in 1913-14. The annual average for the decade 1903-4 to 1912-13 was 207,696 tons, as against 153,052 for the preceding decade. The increase in production of sugar during the last decade over the preceding one was 35.7 per cent, as compared with 47.8 per cent increase in area used for cane. The annual exports of sugar from Mauritius for the 15 years 1899-1913 were 204,671 tons, of which 26,089 tons, or 12.7 per cent, went to the United Kingdom. The exports to the United Kingdom increased from 8.1 per cent during the five years 1899-1903 to 19.2 per cent for the five years 1909-1913.

During the sugar campaign of 1913 there were 59 sugar factories in operation, and the average sugar extraction per weight of cane was 10.7 per cent. The 1913 crop of cane exceeded all previous years, and the factories were required to operate at their full capacity and worked from 18 to 20 hours per day.

JAPAN.**CANE SUGAR.**

The territory upon which sugar cane is grown in Japan is limited to a small area in the southern part of Japan proper. The total area under cultivation in 1913 was 14,000,000 acres, of which 51,293 acres, or 0.4 per cent, was in sugar cane. The area under cane decreased from 46,338 acres in 1906 to 43,493 in 1909, but increased to 51,293 in 1913 and to 53,300 in 1914. The production of cane amounted to 851,130 tons in 1906, decreased to 610,195 in 1907, and increased to 946,348 in 1912 and to 954,758 in 1914. The yield of cane per acre was 18.37 tons in 1906, but fell to 13.69 tons in 1907 and increased to 17.15 and 17.91 tons, respectively, for 1913 and 1914. The number of sugar factories in operation has more than doubled during the last 10 years. There were 7 factories in 1904-5, which were increased to 16 in 1913-14. The cane used for sugar in 1906-7 amounted to 592,693 tons, or 97.1 per cent of the production. In 1911-12 the cane used amounted to 941,550 tons, or 99.4 per cent of the production. The production of sugar increased from 56,078 tons in 1906-7 to 75,797 in 1911-12, but decreased to 68,867 in 1912-13.

and again increased to 72,613 in 1913-14. The production of sugar per acre increased from 2,517 pounds in 1906-7 to 2,685 in 1912-13 and to 2,725 in 1913-14. The production of sugar per ton of cane decreased from 189 pounds in 1906-7 to 161 pounds in 1911-12, and the percentage of sugar extraction per weight of cane for the same years was 9.46 and 8.05 per cent, respectively. The number of people employed in the sugar factories increased from 737 in 1904-5 to 1,187 in 1913-14, or an average of 1,156 for the decade, of which 1,028 were men and 128 were women. The length of the sugar-manufacturing season in Japan varied from 261 days in 1904-5 to 226 in 1908-9, to 298 in 1910-11, and to 294 in 1913-14, or an average of 279 for the decade.

The imports of sugar into Japan decreased from 273,650 tons in 1904 to 87,631 in 1911 and increased to 362,534 in 1913. The exports gradually increased from 16,349 tons in 1905 to 111,670 in 1913. The imports have been approximately double the production and the exports two-thirds of the production, except in 1913, when the exports considerably exceeded production.

FORMOSA.

CANE SUGAR.

The production of sugar in Formosa has increased 400 per cent during the period 1903-1914. The production was slightly less than 40,000 tons in 1903-4, which increased to 222,000 tons in 1914-15. The average production for the five years 1903-4 to 1907-8 was 65,881 tons, as compared with 193,126 tons for the five years 1910-11 to 1914-15, an increase of 193.1 per cent. The area used for cane in 1913 was 165,094 acres, from which was produced 350,885 tons of cane, an average of 6.13 tons per acre. The sugar obtained from this cane amounted to 79,368 tons, an average extraction of 10 per cent per weight of cane. The first modern sugar factory is said to have been erected in Formosa in 1902 by Americans. Prior to that date the manufacture of sugar was by the open-kettle process, and the cane was ground in wooden roller mills operated by buffaloes. The small mills have decreased in number, while the modern factories have increased from 1 in 1902 to 33 in 1912. The 33 factories have a crushing capacity of 24,000 tons of cane per day, and produce only raw sugar. As late as March, 1913, there was only one refinery in Formosa, and the sugar exported was refined in the country of destination. Most of the sugar was exported to Japan, where it was refined, part of which was retained for consumption.

STRAITS SETTLEMENTS.

CANE SUGAR.

The area used for sugar cane in the Straits Settlements increased from 9,825 acres in 1899 to 15,020 in 1902, but decreased to 2,934 acres

in 1912. Statistics of sugar production are not available, but the exports increased from 36,390 tons in 1899 to 60,274 in 1905, to 76,238 in 1912, and decreased to 65,172 in 1913. The imports of sugar for this 15-year period exceeded the exports and varied from 41,099 tons in 1899 to 111,083 in 1913. During the last 10 years the rubber industry has gradually taken the place of sugar manufacture.

FIJI ISLANDS.

CANE SUGAR.

In the Fiji Islands the area of sugar cane and the quantity of sugar produced during the last 20 years have increased more than 200 per cent. The area in 1893-94 was 15,759 acres; 10 years later it had increased to 33,304, and in another 10 years, or in 1913-14, the area was 48,208 acres, or three times the area in 1893-94. The annual area during the decade 1903-4 to 1912-13 was 42,850 acres, as against 21,196 for the preceding decade, an increase of 102.2 per cent. The output of sugar shows an even greater increase than the area. In 1893-94 the sugar produced amounted to 17,236 tons, which increased in 1903-4 to 52,011, and in 1913-14 to 110,441, or more than six times the quantity produced in 1903-4. The annual production of sugar for the decade ending with 1912-13 was 68,080 tons, as against 31,737 for the preceding decade, an increase of 114.5 per cent. The figures used for sugar production prior to 1903-4 are exports, but as a very small quantity of sugar is retained for home consumption the production figures, if available, would show very little change in the percentage.

AUSTRALIA.

CANE SUGAR.

The cane-sugar industry of Australia is of comparatively recent development. In 1870-71 the production was about 3,000 tons. In 1900-1901 it had increased to about 100,000 tons, and in 1910-11 the production was more than 250,000 tons. The area devoted to the growing of cane is a narrow strip along the eastern coast beginning with the three northern counties of New South Wales and extending almost to the extreme northern part of Queensland. About 1 per cent of the land under cultivation is devoted to the growing of cane, of which about 90 per cent is in Queensland. The total area under all crops in 1903-04 was slightly more than 9,000,000 acres, which increased gradually to more than 13,000,000 acres in 1912-13. The total area under sugar cane increased from 131,698 acres in 1903-4 to 155,567 in 1912-13. As the sugar cane requires about 18 months to mature, the total area under cane for any one year really includes cane for two successive harvest seasons. The planting season begins in February and ends in October, and the harvest season extends from June to the following January. The area of cane used for sugar during the period 1903-4 to 1912-13 varied from one-half to two-thirds

of the area under cane. The actual area of cane used was 65 per cent of the total area under cane. The cane is usually planted about once in four years. One planting produces one crop of plant cane and three crops of ratoon or stubble cane. The average annual yield of cane per acre was 18.55 tons for the 10 years 1903-4 to 1912-13, ranging from 22.36 tons in 1910-11 to 15.09 tons in 1912-13. The average yield for New South Wales was 25.57 tons, compared with 17.47 tons for Queensland. The total value of all farm crops in 1907-8 was \$148,000,000, which increased to \$223,000,000 in 1912-13. The value of the sugar cane was \$8,393,000 and \$4,353,000 for the same years. The sugar-cane crop yielded the farmer \$54.17 per acre in 1907-8, but decreased gradually to less than one-half that amount, \$24.84, in 1912-13.

The growers were paid for their cane in proportion to the sugar content, which varies considerably, thus causing a fluctuation in price of about \$3 per ton, the lowest price being about \$2 and the highest about \$5. The average price received by the grower during the period 1907-8 to 1912-13 was slightly in excess of \$3 per ton.

The number of sugar mills decreased from 59 in 1903-4 to 50 in 1912-13. These mills employed more than 4,500 people, of which 10 were women in 1910-11, which was increased to 12 the following year and to 13 in 1912-13. The sugar output of these mills has gradually increased and ranged from 125,058 tons in 1903-4 to 144,776 in 1912-13, or an annual average for the 10 years of 193,150 tons. The quantity of cane required to produce 1 ton of raw sugar varied from 8 tons in the northern part of Queensland to 10 tons in the southern part, or an average sugar extraction of 10.5 to 11.5 per cent of the weight of the cane. The quantity of sugar produced per ton of cane varied from 210 to 230 pounds. In addition to the sugar produced there was an annual production of more than 6,000,000 gallons of molasses.

The sugar industry of Australia has been encouraged by a Government bounty of 6 shillings per long ton (\$1.30 per short ton) of cane or beets grown by white labor. The sugar produced by white labor exceeded that produced by colored labor for the first time in 1906-7. In 1902-3 the sugar produced by colored labor was 68 per cent of the total, which decreased to 5 per cent in 1912-13. The production of sugar is insufficient to supply the home demand. The imports have averaged 54,638 tons during the period 1903-1913, while the exports averaged 576 tons during the same period. The sugar consumed during the 10 years 1903-1912 amounted to 238,097 tons, or a per capita consumption of 112.96 pounds.

Data relating to sugar beets are available only for the years 1910-11 to 1912-13. The beets were mostly grown in Victoria, but a small area in Tasmania was devoted to this crop. The area for the

three years, respectively, was 472, 756, and 938 acres. The total yield was 6,871, 4,540, and 7,006 tons, and the average yield per acre was 14.56, 6.00, and 7.47 tons. The total farm value of the beet crop was from \$20,000 to \$30,000, or a value of \$3.68 to \$4.47 per ton. The value per acre was given as \$49.49, \$24.75, and \$29.76, respectively, for each of the three years.

In July, 1902, the excise tariff act came into operation. A duty of £6 per long ton, or 1.3 cents per pound, was imposed on imported sugar. This act also provided for an excise tax on all Australian sugar used for home consumption. The tax amounted to £3 per long ton, or sixty-five one-hundredths of 1 cent per pound. Out of this tax a rebate or bounty of £2 per long ton, 0.43 cents per pound, or 86.9 cents per short ton of cane, was paid to the grower for cane produced by white labor. This bounty was made to the grower on the basis that it took 10 tons of cane to produce 1 ton of sugar. In December, 1905, the tax was increased to £4 per ton, 0.82 cents per pound, for domestic sugar consumed locally. The bounty also was raised to £3 per long ton of sugar, 0.65 cents per pound, or 6 shillings per ton, \$1.30 per short ton of cane, yielding 10 per cent of commercial sugar. In July, 1913, the excise and bounty acts were repealed, the growers agreeing not to employ colored labor on the sugar plantations.

EGYPT.

CANE SUGAR.

The territory of Egypt used for the growing of sugar cane is in the valley of the Nile, and this crop is mostly an irrigated one. During the decade 1903-4 to 1912-13 the territory known as Upper Egypt contained 92.9 per cent of the area under cane, while only 7.1 per cent was in Lower Egypt. The total area under cultivation in Egypt during the above decade averaged 7,911,000 acres annually, of which 51,296 acres, or 0.6 per cent, was used for sugar cane. The area used for cane has decreased considerably during the last 10 years. The area under cane in 1903-4 was 69,470 acres, 40,027 in 1907-8, and 50,310 in 1912-13, or an average of 51,296 for the decade. The total yield of cane is not available, but the cane used for sugar decreased from 10.81 tons per acre in 1903-4 to 6.98 tons in 1907-8, and increased to 16.24 tons in 1912-13, or an average of 11.11 tons for the decade. The cane used for sugar decreased from 729,265 tons in 1903-4 to 279,388 in 1907-8, and increased to 816,952 in 1912-13, or an average of 569,779 for the decade. The production of sugar shows a decrease from 71,172 tons in 1903-4 to 28,154 in 1907-8, but increased to 83,135 in 1912-13, or an average of 56,514 for the decade. The sugar content of the cane varied from 12.92 per cent in 1903-4 to 12.88 per cent in 1912-13, the average for the

decade being 12.56 per cent. The percentage of sugar extraction per weight of cane varied from 9.8 per cent in 1903-4 to 10.2 in 1912-13, an average of 9.9 for the decade, a loss of approximately 3 per cent, part of which was in the molasses. The sugar extraction per ton of cane decreased from 215 pounds in 1903-4 to 191 in 1904-5, increased to 236 in 1909-10, decreased to 224 in 1912-13, and averaged 219 for the decade. The production of sugar per acre was 1,849 pounds in 1903-4, 1,406 in 1907-8, 3,305 in 1912-13, and averaged 2,203 for the decade. The exports of sugar during the last 10 years show a decrease, while the imports show an increase. The exports were 25,310 tons in 1904, 4,329 in 1908, 5,658 in 1913, and an average for the 10 years of 11,387 tons. The imports were 22,922 tons in 1904, 58,703 in 1908, 36,305 in 1913, and an average of 40,576 for the decade. The domestic production of sugar has not been quite equal to the home requirements, as the annual imports during the last 10 years were nearly 30,000 tons in excess of the exports. The exports for the decade 1904-1913 were 20.1 per cent of the production, as against 71.8 per cent for imports. The consumption of sugar increased from 68,784 tons in 1904 to 113,782 in 1913, an average of 85,703 for the decade, or an average per capita consumption of 15 pounds. The consumption of sugar for the decade was 51.6 per cent in excess of the production. The planting season for sugar cane is from February to May, and the harvest season is from October to December, the average length of the sugar-making season being usually less than 100 days.

NATAL.

CANE SUGAR.

The area used for the growing of sugar cane in Natal is in the lowlands along the coast and increased from 13,345 acres in 1893-94 to 33,282 in 1903-4 and to 64,938 in 1911-12. The production of sugar increased from 17,699 tons in 1893-94 to 41,062 in 1901-2, to 86,790 in 1909-10, and to 96,880 in 1913-14.

In 1909-10 the total area under cultivation was 451,638 acres, of which 46,567 acres, or 10.3 per cent, was in sugar cane. The area of cane cut for sugar that year was 24,512 acres, or 52.6 per cent of the area under cane. The yield of sugar per acre was 2.9 tons. There were 42 sugar factories in operation, of which 39 were operated by steam power, one by oil engine, and 2 by water power. The greater portion of the sugar produced in Natal is consumed locally. The exports were small and decreased from about 35 per cent of the production in 1899 to 2 per cent in 1913.

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HENRY S. GRAVES, Forester



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PROFESSIONAL PAPER

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TRUE MAHOGANY.

By C. D. MELL, *Forest Examiner.*

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INTRODUCTION.

The name "mahogany" is applied commercially to more than 50 different woods. True mahogany, however, is produced by only two closely related species of trees (*Swietenia mahagoni* Jacq. and *Swietenia macrophylla* King), which are natives of tropical America. These were looked upon as the same species (*Swietenia mahagoni*) until long after mahogany had become well known in the timber trade of the world, so that when a botanical distinction between them was finally recognized it was only natural that the same name should continue to be applied to the wood of both.

There appears to be a widespread popular belief that true mahogany may be had from many parts of the world. As a matter of fact, true mahogany grows naturally only from the tropical part of Florida and adjacent keys and islands to the northern part of South America (fig. 1). The extensive commercial use of the name "mahogany," either with or without a qualifying adjective, such as African, Indian, Philippine, etc., for so many other woods indicates that the characteristics and sources of supply of true mahogany are still imperfectly known. Some of these other woods in their structure bear little more than a general resemblance to true mahogany, though skillful finishing may make them very much like it in outward appearance. The majority of them can be distinguished from

true mahogany by the aid of an ordinary hand lens, although in exceptional cases a high-power microscope is necessary. Most consumers of mahogany attempt to distinguish the wood by its general appearance, grain, weight, and color. Such tests, however, can not



FIG. 1.—Range of true mahogany (shown by shaded areas).

be relied upon in all cases and are trustworthy only for those who have for a long time worked or otherwise handled the woods.

Perhaps half the lumber now sold and used as mahogany is not true mahogany, the available supply of which is insufficient to meet the large demand for mahogany furniture, interior finish, and the like. During the year ending June 30, 1914, the total value of true

mahogany and other woods called mahogany shipped into the United States amounted to approximately \$5,000,000. They may be divided into two classes, according as they are used for (1) construction and interior finish or (2) furniture and cabinet and other ornamental work. To the first class (used also largely for office and bank fixtures) belong some grades of true mahogany, chiefly from the lowlands of Mexico and wanting figure and luster, and other "mahogany" woods that have very little figure. The second group is made up of the best grades of true mahogany and the more highly figured and ornamental of the other "mahoganies."

The present bulletin confines itself to a discussion of true mahogany.

COMMON NAMES.

Besides its most common name, mahogany, the wood of the two species of *Swietenia* has received a number of other names either locally or in the market. Some of these indicate the place or region where the wood is cut, or the port from which it is shipped. Thus, Tabasco, a State in Mexico, supplies the so-called Tabasco mahogany, as distinguished, for example, from San Jago mahogany, which comes from San Jago, Cuba. Similarly, mahogany from Jamaica, Cispata, Cuba, Honduras, Nicaragua, Panama, Spanish America, Colombia,¹ Mexico, Nassau, Santo Domingo, Haiti, Yucatan, West Indies, South America, Belize, Trupillo, Guatemala, Porto Plata, Laguna, Corinto, and Central America bears as a distinctive part of its local or trade name that of the town, port, State, or region from which the wood is derived. In reference to the excellence or inferiority of the wood from different regions, Santo Domingo mahogany, for example, is considered the most desirable grade. This comes mainly from slow-growing trees on high, dry ground and is relatively hard compared with the soft, spongy "bay mahogany" (*Swietenia macrophylla*) obtained from rapid-growing trees in the moist soil of British Honduras and along the coast of southern Mexico. "Baywood" is another trade name used for the wood from the Mexican lowlands.

The following additional trade, local, and foreign names are also applied to true mahogany:

Caoba² or caobo (Spanish name in Cuba, Mexico, Central and South America).

Mahagoniholz or acajouholz (German).

Pao magno (Portuguese).

Albero di acajou (Italian).

Madeira or madeira wood (Florida and Bahamas).

¹ There is also a wood marketed under the name "Colombian mahogany" which is not true mahogany. See Forest Service Circular 185, Colombian Mahogany.

² In Costa Rica, Caoba, a name probably of Indian origin, is applied also to *Guarea caoba* C. D. C. and *Carapa guianensis* Aubl.

Redwood (now a rare trade name).

Zipilote colorado and zipilote negro (interior of Mexico).

Acajou, acajou a meubles, bois d'acajou, and mahagon (French in Venezuela and West Indies).

Cedro cebolla (Colombia, S. A.).

GEOGRAPHICAL DISTRIBUTION.

At one time mahogany was believed to be a native only of the region extending approximately from the northern boundary of Costa Rica northward to Tampico in Mexico. It is now known, however, to extend from the extreme southern point of Florida to the West India Islands, and along the Gulf coast in Mexico from Tampico southward through Central America and into South America. (See fig. 1.) Formerly it was very plentiful on the Island of Trinidad and along the coast of the mainland to Venezuela. It is common in northeastern Colombia and Venezuela. In general, the small-leaved species (*Swietenia mahagoni*) is found in Florida, the West Indies, Central and South America, and elevated parts of Mexico. It is common at elevations of from 3,000 to 4,000 feet, where it grows slowly but produces wood of the best quality. The commercial distribution of the large-leaved species (*Swietenia macrophylla*) is not so well known, but it seems to be most abundant in British Honduras and along the coastal plains of southern Mexico.

From 100 to 150 years are required for a mahogany tree to reach merchantable size. It grows both on high dry ground and in low moist situations. It is on the latter sites, in Mexico and Central America, that the largest timber is produced.

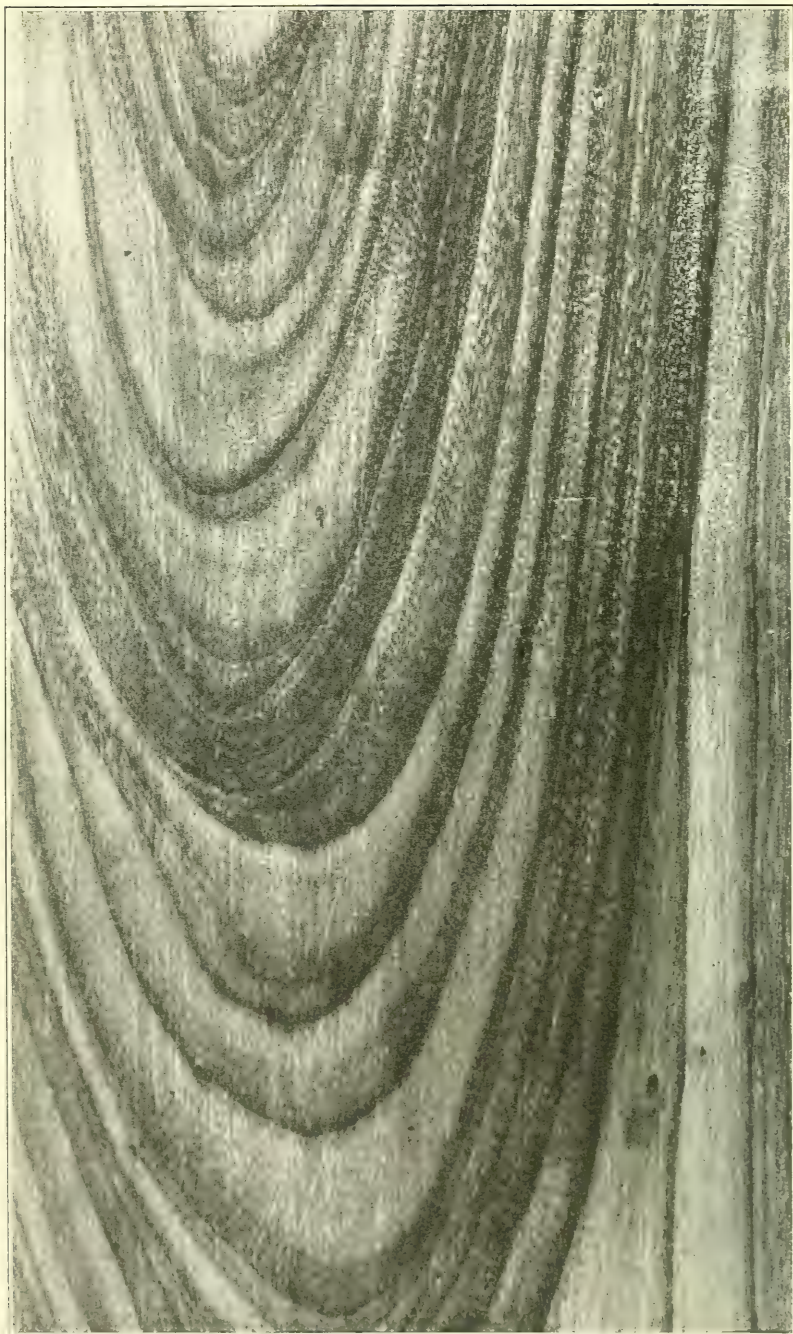
Both species have been planted experimentally in India, Burma, Africa, and other tropical countries, first being introduced at the Calcutta Botanic Garden toward the close of the eighteenth century. Since 1865 its artificial extension over India, Burma, Andaman, and parts of east and west Africa has been fairly rapid. The large-leaved species has been introduced into the Philippine Islands, where it grows very rapidly, but the wood is soft and of an inferior quality.

Provisions are made in several Central and South American countries within the natural range of mahogany to insure continuance of the supply by requiring those who have timber concessions to plant two mahogany trees for every mature one cut. This, however, has been found not only unprofitable, but unnecessary, since natural reproduction on cut-over lands is usually good. At least one large timber company operating in the Republic of Colombia has for over 20 years faithfully carried out the terms of its contract by replanting cut-over areas, but the results are not encouraging. Planted trees often grow very slowly in comparison with those resulting from natural seeding.



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VENEER SHOWING ALTERNATING STREAKS OF LIGHT AND DARK SHADES.



VENEER SHOWING ALTERNATING STREAKS OF LIGHT AND DARK SHADES.

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It is probable that the cultivation of mahogany will never attain commercial importance outside of the tree's original habitat. While it will grow under widely varying conditions of soil and moisture, it seems to do best within the comparatively narrow limits of its natural range. Moreover, the relatively slow growth of *Swietenia mahagoni*, which produces the better wood of the two, is an added handicap. In India, it is true, where conditions are exceptionally favorable, the trees of both species often grow very rapidly, but it is not believed that the planting of mahogany on a commercial scale in India would be a profitable undertaking. Both species are planted extensively as shade trees throughout tropical America. The large-leaved species produces a very dense crown and is regarded as one of the best shade trees; the small-leaved species has an open crown and, like the famous saman tree (*Pithecolobium saman*) of Central and South America, forms a splendid tree for the lawn or park where dense shade is not desirable.

GENERAL CHARACTERISTICS OF THE WOOD.

Mahogany is moderately strong and tough, quite uniform in structure, and may be either moderately open grained or close grained, depending largely on the locality where grown. The wood seasons with comparatively little warping and checking, and once seasoned shrinks and swells very little. This property of holding its shape, together with its handsome grain and figure, makes it one of the most satisfactory cabinet woods and causes shipbuilders to prize it. It takes a beautiful natural-wood polish, is well adapted to stains, and has the particularly valuable quality of taking glue well. The wood is also being used now to some extent for pattern work. Owing to the small size of the pith rays, quarter sawing adds little to its figure. The grain of high-grade mahogany is often very odd and pronounced, and in this form it is the most valuable cabinet wood known. For the most part it is cut into very thin veneer by a special machine to avoid waste. Veneer of great beauty is obtained from crotched pieces which are taken from the tops of trees where the limbs join the trunks. This form is known on the market as "crotch mahogany."

Mahogany is one of the most popular furniture woods, chiefly because of its lasting qualities, color, and grain, and its freedom from warping, shrinking, and checking. Of all the cabinet woods now on the market, however, mahogany shows the greatest variation in quality. Even woods from the same locality do not grade alike. Beauty of grain is the chief property by which mahogany is graded, though closely allied to this is figure or pattern. (Plates I and II.) Size is also a factor in determining the value of mahogany lumber.

The numerous trade names given to mahogany usually imply a difference in grade, as determined by the features just pointed out. Formerly mahogany from Nassau or Santo Domingo was distinguished from Cuban mahogany by the smaller size of the logs, and dealers still carefully discriminate between so-called Spanish or Cuban mahogany and that obtained from other islands of the West Indies. The large trees accessible in Cuba, however, have practically all been cut.

Florida, Cuba, Mexico, and Honduras exhibit distinct features of soil and climate and produce grades of mahogany of characteristic qualities. The difference between woods from the various regions is often so marked that an expert can tell at a glance from which one of them a given piece of wood has come. Trees on the hard, dry limestone soil of extreme southern Florida grow very slowly and produce a wood that is hard, heavy, dark red, and beautifully figured. This mahogany takes a better and more lasting polish than any other grade of the wood. The mahogany of Cuba and Santo Domingo grows in a richer, moister soil, and, as a result, is usually somewhat softer and of lighter weight than Florida mahogany, but nevertheless is of a high grade. It has a close, even grain, and the logs imported seldom average more than 10 cubic feet each. Some of the pores are filled with hard, gritty, white masses which constitute a distinguishing character. Mahogany from those parts of Mexico and British Honduras where soil and climatic conditions are very favorable to rapid plant growth is considerably lighter in weight and often much lighter in color than that from more elevated regions. Mexico produces larger mahogany trees and a greater yield per acre than any other country. Honduras produces logs 40 feet long and 4 feet in diameter. The wood is a beautiful dark color with a more or less wavy figure. Even 6-foot pieces with a wavy grain and including crotches of the trees sometimes bring fabulous prices. Occasionally single logs have been sold for \$3,000. The claim that Mexican mahogany is generally of a much better grade than that from Central America is not true of the grade of Mexican mahogany known as baywood (*Swietenia macrophylla*), which usually sells for much less than the ordinary heavier, darker colored mahogany from regions farther north, which is the small-leaved mahogany (*Swietenia mahagoni*). The dark reddish-colored grades of Mexican mahogany, however, are fully equal and in some instances superior to the Central American wood.

The weight of mahogany varies greatly according to the density of the wood. Florida mahogany is the heaviest, having a specific gravity when dry of 0.842. A cubic foot of it weighs 52½ pounds, and 456 board feet weigh a ton. The better grades from Honduras and Mexico have a specific gravity of about 0.74, 1 cubic foot

weighing approximately 46 pounds, and 520 board feet a ton. The average mahogany wood from Cuba has a specific gravity of about 0.72, and a weight per cubic foot of about 45 pounds, 533 board feet weighing a ton. The lightest mahogany wood is the baywood, from Mexico, which has a specific gravity of 0.561. A cubic foot weighs only about 35 pounds, and about 686 board feet are required to make a ton.

The pale-yellow or whitish sapwood of mahogany is thick in young and in rapid-growing trees and thin in old and in slow-growing ones. In Florida the sap is often less than 1 inch in thickness on the largest trees, with about 25 annual rings of growth. Compared with this, the sapwood of large trees from Mexico and Honduras is often more than four times as thick and contains less than one-half as many rings of growth. The structural characters of the sapwood and heartwood of mahogany are, of course, similar, but the sapwood is almost never used and is generally removed before the logs are shipped to market. If it is not removed immediately after the trees are felled it is apt to become affected by fungi which may also damage the heartwood.

The color of heartwood ranges from a rich light brown to a dark red-brown, the shade becoming deeper with age and exposure. Florida mahogany is the darkest colored, Cuban and Honduras wood come next, and the baywood grade of Mexican mahogany is the lightest colored. These marked differences in color, as also in density and weight, appear to depend entirely upon the rate of growth, which, in turn, is dependent upon soil and climatic conditions.

CHARACTERISTICS OF THE WOOD FROM DIFFERENT REGIONS.

When mahogany comes into the market it is graded without reference to whether it is the wood of the small-leaved or large-leaved species. Timber merchants and wood users are interested primarily in the origin of the wood, which affords them a clue as to its quality.

Mahogany from Florida is the hardest and heaviest of all the West Indian grades. The wood has very narrow annual rings of growth, and the pores are very small, often not more than 0.1 of a millimeter in diameter. The pith rays are broad and quite clearly defined, thus contrasting strongly with Mexican mahogany from the coastal plains, which has pores from two to three times as large, and the pith rays narrower and less numerous.

Cuban mahogany is hard, heavy, and slightly darker in color than that of British Honduras. The annual rings of growth are very narrow, especially in trees grown on the higher elevations. The pores,

which are usually filled with a white substance known as tylosis, are considerably smaller (0.15 millimeter) than the wood from British Honduras, and the pith rays are quite clearly visible to the unaided eye. Cuban mahogany is usually from old, knotty, and decrepit trees grown in high rocky uplands. At present very large logs are rare. The smaller ones now cut are of good quality as far as the character of the wood is concerned and are used chiefly for sliced veneer.

San Salvador mahogany is similar in color, hardness, and weight to that of Venezuela. The annual rings of growth are somewhat less clearly defined and wider than in mahogany produced farther south. The pores are prominent (about 0.2 millimeter in diameter), and the pith rays quite conspicuous, often producing a beautiful effect in radially cut boards. At one time a good deal of mahogany from San Salvador was shipped to England under the name of "Nicaragua wood," and to this country as "Cispata mahogany."

Mahogany from Venezuela is hard, heavy, and dark brown, with a golden tinge, particularly noticeable on the radial surface. The annual rings of growth are more or less prominent, unequal in width, but usually rather wide. The pores are large and visible to the naked eye. The pith rays are numerous and scarcely visible on a smooth transverse section. This wood works well and is exported chiefly to France for fine furniture and interior finish.

Mexican mahogany is the most variable in quality. Although a good deal of the wood from the higher elevations of Mexico superficially resembles that from Cuba, it is on the whole softer and lighter in color, even resembling the wood of the famous Spanish cedar so much used for cigar boxes. The best Mexican mahogany comes from the interior and higher portions of the State of Tabasco, and in size, color, and hardness is superior to the best product obtained in the lowlands farther south. Mexican mahogany has slightly larger pores than the wood from Cuba, and the pith rays are not visible except under a pocket magnifier.

Mahogany from British Honduras contrasts strongly in appearance and in structure with that from other regions. Annual rings of growth are often wanting, so that the wood has a nearly homogeneous structure. It is moderately soft and light in weight, but in quality and color compares favorably with that from Venezuela. The pores are large, often from 0.2 to 0.25 millimeter in diameter, and are usually filled with a dark-brown substance known as tylosis. Pith rays are very narrow and indistinct. Wood from this region is straight grained, usually free from knots, and easily recognized. It is well adapted for inside work where figure is not required.

MARKET VALUE.

The best grades of mahogany sell in New York for from \$175 to \$200 per thousand board feet, while the average run of firsts and seconds brings about \$150.

Specially well-figured Cuban mahogany, suitable for fancy counter tops, and selling for from \$300 to \$400 per thousand, is now very scarce. Culls sell for from \$60 to \$100 per thousand board feet, and commons for from \$100 to \$150. A poor grade of Cuban short stock often sells for \$60, and sometimes as low as \$50, per thousand. The best grades are used for fancy furniture and interior finish; the larger logs with desirable figure, which bring from \$100 to \$150 per thousand board feet scaled, are converted chiefly into veneer. The San Jago mahogany, which comes from San Jago, Cuba, sells for from \$140 to \$165 per thousand. The supply of Cuban mahogany is gradually diminishing. Two grades of Mexican mahogany, alike in their pale color and straight grain, but differing in their hardness, do not finish well and do not improve in color with age. The softer of these, sometimes called "sappy mahogany," sells as low as \$20 or \$25 per thousand. The other grade has few defects and is used for patterns.

USES AND SUPPLY.

The earliest recorded use of mahogany was between 1521 and 1540, when Spanish explorers employed the wood for making canoes and for ship-repair work. Mahogany was again used in 1597 in repairing Sir Walter Raleigh's ships in the West Indies. At this time the wood was called Cedrela, the name applied later to the Spanish, or cigar-box, cedar (*Cedrela odorata* L.). The first use of true mahogany for cabinet work was in 1724 in England. It was probably the first wood of the Western Continent to attract the attention of European timber dealers. Some idea of the enormous consumption of mahogany in England alone may be had from the fact that as early as 1846, when the wood was still valued chiefly for shipbuilding, approximately 85,000,000 board feet were shipped to English ports. Since then the amount has diminished considerably, partly because of gradual exhaustion of the more accessible timber and partly, also, because of the introduction of substitutes.

Its first use in England and Spain was for shipbuilding, and during the eighteenth century it was the chief wood employed in Europe for this purpose. It is particularly suited for planking, waterways, bulwarks, rails, skylights and companions, bitts, gangway ladders, and other deck work. With the later employment of iron, steel, and teak in shipbuilding, mahogany became more important as a furniture wood, though it is still preferred to any other wood for the

framework of small sailing vessels. Large sailing vessels with mahogany framework were sold for enormous prices and manufactured into fine furniture. The outer planking of American yachts is preferably of mahogany, although teak is still used for this purpose. The principal use of mahogany is for high-class furniture; it is also much used for the interior finish of parlor cars, public buildings, hotels, and dwellings, and for office fixtures. It is used very extensively for pianofortes, for astronomical and surveying instruments, and for the cases of all sorts of delicate apparatus, such as scales, microscopes, and microtomes. The present extensive use of mahogany for the interior finish of fine office buildings, particularly in this country, has created a demand for specially large-dimension boards, obtained from logs which come from Mexico and British Honduras.

As early as 1850 English timber merchants feared an exhaustion of the world's supply of West Indian mahogany, then the best-known and most highly prized of the different grades of woods. As a result, timber prospectors began to search for other woods that could be substituted, and after the British conquest of India a number of different woods resembling mahogany were shipped from that country to England. So far as is now known the introduction of these woods marked the beginning of the substitution of mahogany-like woods for true mahogany. African "mahogany" was first imported into England in 1833, when 58 logs were sold in Liverpool, but it was not until about 1878 that it became commercially important. African "mahoganies" are now among the leading fancy cabinet woods in England and also have an important place in the principal American markets.

Immediately after the acquisition of the Philippine Islands by the United States several other woods entirely unrelated to true mahogany began to be exploited and sold under the name of "Philippine mahogany." A good deal of this material has been shipped into the United States during the last decade, and the importations have been rapidly increasing.

Millions of feet of true mahogany are still available, however, in remote places difficult of access. No one knows just how much standing mahogany is left, though vast areas are believed to exist in Mexico and Central America.

The early impression that the supply of mahogany was nearing exhaustion came from the practice of cutting only the easily accessible trees along and near waterways. Wood drawn from the tropical forests for nearly 200 years has been obtained mainly from territory bordering water courses, while that farther inland remains untouched. The mountain forests of Cuba still contain a large supply of the finest mahogany, but it would cost more to transport the logs to shipping points than they would bring in the market. The supply of Santo

Domingo mahogany within easy reach of water is now almost entirely exhausted, and the logs coming from there, as well as from Cuba, are from lands already cut over. In consequence, they are small, crooked, and often of low grade.

The best available mahogany timber lands of the American tropics and subtropics are now largely controlled by American and English concessionaires who, a number of years ago, when the price of mahogany was lower than at present, foresaw its future value and obtained options on large tracts. Now it is almost impossible to obtain a workable concession of mahogany timber at a price low enough to permit lumbering at a profit.

Mexico, Cuba, Central America, and South America are the chief producers of mahogany, other regions within the range of the tree contributing comparatively small quantities. British Honduras and Mexico each supply nearly one-third of the total imports of true mahogany. (See Table II.)

English timber merchants have been exploiting mahogany in British Honduras for many years, and at present several American companies are also operating there. All these companies have their shipping point at Belize, to which logs are towed principally down the Hondo River.

The State of Tabasco yields the greater part of the mahogany from Mexico. The principal points in Mexico from which mahogany is exported are: Tecolutia, Frontera, Cazes, Laguna, Santa Ana, Tuxpan, Tampico, Chiltepec, Campeche, Coatzacoalcos, Minatitlan, Nautla, Tonalá, Cheucan, and Tlacotalpan.

Mahogany has been exported from Tabasco for a number of years because the seacoast of the State has numerous bays and harbors which are safe for large vessels at all seasons. Into these bays run many large rivers, chief among them the Usumacinta, Iryobva, and Tancockapa. The Usumacinta River is about 400 miles long, forming a part of the boundary between Guatemala and Mexico, and is navigable for nearly 240 miles above its mouth. The country all along the river abounds in mahogany, and large quantities are cut annually, brought to the river, and towed down to the landing points. At present five American companies are operating within the State of Tabasco, one of which is said to ship annually 5,000 tons, or approximately 2,500,000 board feet of mahogany.

While very desirable mahogany comes from the other tropical American countries, their production is considerably less. Some of the finest mahogany comes from southern Florida and the adjacent keys. On the keys the wood is called *madeira*,¹ and is commonly thought not to be mahogany, but a different and much better wood.

¹ Not to be confused with *Tamarindus indica* L., the wood of which is sometimes known as "madeira."

On the island of Andros (Bahamas) it is often used for board walks and other purposes requiring durability. Mahogany grows on most of the West India Islands. In the early days of railroad and bridge building there and in Central America the lasting qualities of mahogany made it a favorite wood for railroad ties and bridge timbers, which greatly reduced the supply.

IMPORTATIONS.

Previous to 1892 there is no complete record of the quantity of mahogany shipped to the United States, nor even of the countries from which mahogany was imported. Since that year, however, a record has been kept by one of the large importers¹ of the mahogany entering New York from the chief centers of production. The following table gives the quantities imported since 1892 from each of these regions:

TABLE I.—*Shipments of true mahogany entering New York from 1892 to 1910, inclusive.*

| Year. | Cuba. | Mexico. | Central and South America. | Total. |
|-----------|-----------------------|-----------------------|----------------------------|-----------------------|
| | <i>Thousand feet.</i> | <i>Thousand feet.</i> | <i>Thousand feet.</i> | <i>Thousand feet.</i> |
| 1892..... | 3,884 | 7,871 | ..... | 11,755 |
| 1893..... | 5,960 | 10,941 | ..... | 16,901 |
| 1894..... | 1,506 | 3,909 | ..... | 5,415 |
| 1895..... | 2,549 | 5,818 | ..... | 8,366 |
| 1896..... | 451 | 6,794 | ..... | 7,244 |
| 1897..... | 94 | 6,202 | 1,756 | 8,053 |
| 1898..... | 92 | 9,396 | 6,541 | 16,034 |
| 1899..... | 689 | 11,477 | 8,985 | 21,150 |
| 1900..... | 3,615 | 9,557 | 4,186 | 17,357 |
| 1901..... | 3,822 | 7,877 | 3,302 | 15,000 |
| 1902..... | 6,043 | 6,940 | 3,407 | 16,390 |
| 1903..... | 4,742 | 9,145 | 3,580 | 17,466 |
| 1904..... | 1,564 | 7,043 | 2,842 | 11,448 |
| 1905..... | 1,829 | 3,195 | 2,615 | 7,638 |
| 1906..... | 3,883 | 4,164 | 1,563 | 9,609 |
| 1907..... | 3,458 | 8,387 | 3,304 | 15,149 |
| 1908..... | 1,796 | 5,205 | 2,597 | 9,598 |
| 1909..... | 3,037 | 3,452 | 11,557 | 18,046 |
| 1910..... | 2,576 | 7,983 | 2,128 | 12,686 |

The logs imported from Central and South America from 1892 to 1896, inclusive, are included with those quoted from Mexico. Fluctuations in the amounts of mahogany imported into this country from one year to another can not be attributed to any particular cause. Imports of 1894 to 1897, inclusive, were all low, averaging a little less than 7,750,000 feet annually. During the seven years which followed the annual importations averaged approximately 16,000,000 feet, in the banner year (1899) amounting to 21,149,750 feet.

Since 1892 Mexico has shipped to the port of New York upward of 136,000,000 feet of true mahogany, while since 1897 Central and

¹ Mr. Geo. F. Herriman, New York City.

South America have shipped about 50,000,000 feet. Although Cuba ships to this country more logs than either Mexico or Central and South America the number of board feet is much below that of Mexico, being approximately only 52,000,000 feet during the last 19 years. The other main ports of entry for true mahogany are Boston and New Orleans.

It is practically impossible to ascertain just what proportion of the wood entering these ports as mahogany is true mahogany. A fair approximation has been reached, however, by grouping¹ together the imports from countries within the range of true mahogany and those outside of its natural range. The following table shows these approximations:

TABLE II.—Quantity and value of true mahogany and other woods imported as mahogany (unsawed) from different countries during the fiscal year ending June 30, 1914.²

| Country. | True mahogany. | | Other "mahogany" woods. | |
|-------------------------|----------------|-----------|-------------------------|--------------------------|
| | Quantity. | Value. | Quantity. | Value. |
| | <i>M feet.</i> | | <i>M feet.</i> | |
| British Honduras..... | 11,074 | \$781,838 | | |
| Africa..... | | | ³ 32,441 | ⁴ \$2,377,502 |
| Colombia..... | 13 | 746 | | |
| Cuba..... | 2,988 | 193,692 | | |
| Guatemala..... | 718 | 43,701 | | |
| Honduras..... | 6,591 | 368,431 | | |
| Mexico..... | 10,381 | 785,148 | | |
| Nicaragua..... | 4,933 | 290,502 | | |
| Panama..... | 28 | 1,321 | | |
| Santo Domingo..... | 537 | 34,589 | | |
| Philippine Islands..... | | | 717 | 44,552 |
| Other countries..... | 44 | 2,807 | 5 | 297 |
| Total..... | 37,307 | 2,502,775 | 33,163 | 2,422,351 |

Table II shows that about 4,000,000 feet more of true mahogany was imported by the United States than of the other "mahoganies" during the fiscal year ending June 30, 1914. It is probable that some of the mahogany reported from the different mahogany-producing countries is not true mahogany; it is also probable that a considerable quantity of wood which is not true mahogany and is marketed in this country as mahogany is imported under some other name. The total quantity of true mahogany is, therefore, probably less than that of the other woods.⁵ The bulk of true mahogany,

¹ Data for this purpose were derived from the Department of Commerce.

² More recent statistics not given on account of abnormal trade conditions.

³ Only 13,423,000 feet were imported directly from Africa. The remainder constitute reshipments from England, Germany, and France.

⁴ English shippers include insurance and freight in their statement of export values, which accounts for the comparatively high cost per thousand board feet.

⁵ A good deal of sabicu (*Lysiloma sabicu* Benth.) and Spanish cedar (*Cedrela odorata* L.) is shipped from Cuba as mahogany. Colombia exports the Colombian mahogany (*Cariniana pyriformis* Miers.), which is not the true mahogany. Honduras, Guatemala, and Mexico export nispero (*Achras sapota* L.) and Spanish cedar as mahogany.

as will be seen, comes from British Honduras and Mexico, which together furnished 58 per cent. Santo Domingo, Panama, Nicaragua, Honduras, Guatemala, and Colombia furnished 34 per cent, and Cuba 8 per cent.

While the actual quantities of true mahogany and other "mahoganies" imported into the United States by different countries can not be ascertained, Great Britain is known to be first as a source of the latter, which come chiefly from Africa and reach the American markets by reshipment from London and Liverpool. Of the total amount of true mahogany and other "mahoganies" imported, Great Britain supplied 18,289,000 feet, or 26 per cent (by reshipment from points of origin), and Africa furnished 13,423,000 feet, or about 19 per cent, through direct shipment. Table III shows the quantities and value of mahogany (true and other) imported by the United States from 1901 to 1914.¹

TABLE III.—*Quantity and value of true mahogany and other mahoganies (unsawed) imported by the United States from 1901 to 1914.*²

| Year. | Quantity. | Value. |
|-----------|-----------------------|-------------|
| | <i>Thousand feet.</i> | |
| 1901..... | 32,281 | \$1,752,612 |
| 1902..... | 44,795 | 2,361,483 |
| 1903..... | 48,387 | 2,783,679 |
| 1904..... | 50,370 | 2,690,382 |
| 1905..... | 31,844 | 1,977,894 |
| 1906..... | 36,619 | 2,470,072 |
| 1907..... | 51,899 | 3,263,718 |
| 1908..... | 41,678 | 2,566,594 |
| 1909..... | 39,828 | 2,479,976 |
| 1910..... | 44,524 | 3,224,152 |
| 1911..... | 43,914 | 3,171,398 |
| 1912..... | 43,194 | 3,038,043 |
| 1913..... | 66,318 | 4,839,625 |
| 1914..... | 70,470 | 4,925,126 |

METHODS OF LOGGING AND TRANSPORTATION.

Formerly all logs were squared by hewing, usually in the forest. The purpose of this was partly to show the figure of the wood, but mainly to remove the useless sapwood. Few trees are cut in Mexico and Honduras that will not square 18 inches or over. The removal of the worthless sapwood by squaring the logs resulted in a very great waste of the best heartwood, particularly near the butt ends, the most valuable part of the logs. Since there is no duty at present on cabinet woods, and transportation is comparatively cheap, a relatively large saving of valuable wood can be effected by shipping mahogany logs in the round. Much of the sapwood may, of course, be cut away before shipment, but under present methods of handling even this added expense seems useless. Another marked waste by

¹ Data for this purpose were derived from the Department of Commerce.

² Fiscal years ending June 30.

past methods of lumbering was in the practice of leaving high stumps. With a large tree the stump is one of the most valuable parts, but it is seldom utilized. The trunks of mahogany trees are disproportionately large at the bases, and native laborers in the Tropics cut the stumps high to avoid the extra work of chopping through the enlarged buttress, or "spurs" which spread out and form massive triangular braces often extending from 8 to 10 feet beyond the main axis of the trunk (Pl. III). The trunks are so tapering that if a tree is cut above this basal swelling from 200 to 500 board feet of the choicest wood may be left in a single stump. The spurs themselves also contain uniquely figured wood which would doubtless command fancy prices. Needless waste of this sort is being eliminated in the case of far less valuable trees than mahogany.

Operators now exploiting mahogany in Mexican and Central American forests have pretty generally abandoned the primitive methods of felling, hauling, rafting, or loosely floating the timber to shipping ports. Instead of snaking or hauling logs to river banks with oxen and clumsy conveyances, up-to-date methods of transportation are now usually employed. There is also a better systematizing of the work. While felling is in progress men are building railroads and bridges over which carloads of logs are hauled to the port, where the timber is placed on steamers for final shipment. Even carrying logs by rail to inland waterways, where they are turned adrift and floated down to the ships at tidewater, is done less frequently now, because the logs are so bruised and splintered by striking rocks in their transit down the river that they have to be hewed and sawed off at the ends to remove the battered, useless wood.

BOTANICAL CHARACTERISTICS.

The mahogany trees (*Swietenia mahagoni* Jacq.)¹ and (*Swietenia macrophylla* King.)² are among the most majestic and beautiful evergreen trees of tropical America. They are members of the family *Meliaceae*, to which belongs the closely related and well-known China tree (*Melia azedarach* L.), extensively planted for shade in the Southern States. In favorable locations mahogany at-

¹ Jacquin, who described this tree in 1760, named it in honor of the celebrated Baron von Swieten, physician to Maria Theresa, Empress of Germany. The specific name *mahagoni* is derived from the original French name *mahagon*. Botanists follow the original spelling of the word *mahagoni*, while the Anglicized name is spelled *mahogany*.

² The mahogany of British Honduras and coastal plains of Mexico is a distinct species. Zuccarini (in Abh. Akad. Muench. II (1831-1836) 355, L. T.-Mexico) described another species, *Swietenia humilis*, which is regarded by the Mexicans as distinct from the other two kinds. It is called gateado (Conzatti, C.-Flora sinoptica Mexicana. Oaxaca. 1897), or flor de venadillo, to distinguish it from the larger tree (*Swietenia mahagoni* Jacq.), which goes under the name of caoba, rosadillo, tozopilotlizontecomatl, tzopilotlzonecomatl, zopilotequahuatl, zopilote, or zopilotl. Two other kinds, commonly known as zopilote Colorado or zopilote negro, are recognized by Mexicans, but these are not described botanically and can not now be regarded as distinct forms.

tains large dimensions, some trees measuring 4 to 6 feet in diameter just above the enormous root swelling (Pl. III), with a height of from 80 to 100 feet. Exceptional trees are known to have reached a diameter of 12 feet. Trunks are frequently clear of branches for from 40 to 50 feet, above which is a broad oval-shaped crown. The pinnately compound leaves are made up of oval lance-shaped leaflets (fig. 2, *a*), which are light green in color, smooth and shining above, and slightly brownish on the under surface. The small whitish or purplish flowers (fig. 2, *b* and *c*) are borne during July and August, and by October or November the large dark-brown seed pods (fig. 3) are ripe. The latter are from 1 to 2 inches in diameter and from 3 to 6 inches long. The trees of these two species can be readily distinguished. *Swietenia mahagoni* has rather small leaves, an open crown, and the pods are seldom over 3 inches long; *Swietenia macrophylla* has larger leaves, a dense crown, and the fruit pods are from 3 to 6 inches long.

The commercial distinctions made in mahogany from different regions have a basis in the gross and minute structure of the wood. Regions of like climatic and soil conditions as a rule produce mahogany of similar or nearly similar structural characteristics and qualities. In the matter of weight and hardness, however, there are occasional exceptions to this general rule. As already pointed out, Florida mahogany is almost invariably harder and heavier than that from Cuba or Mexico. Individual trees from Cuba or Mexico, however, may yield very much harder and heavier wood than the average grades from Florida. Weight and hardness therefore are not invariable means of distinguishing mahogany from different regions. The chief constant difference in the mahogany of the various regions lies in the presence or absence of the annual rings of growth, in their width, and in the character of the pith rays.

True annual rings are not formed regularly in the wood of mahogany farther south than British Honduras, owing to the fact that growth continues practically throughout the year. Mahogany wood produced north of British Honduras commonly shows in transverse sections more or less distinct annual rings of growth. These rings are made prominent, not as in ring-porous hardwoods of the Temperate Zone, by rows of large pores in that part of the ring formed in the beginning of the growing season, but by an abrupt reduction of the radial diameter of the outer rows of wood fibers formed at the end of the growing season, as well as by several rows of large wood fibers, tracheids, and wood-parenchyma fibers formed in the next succeeding layer. This narrow line of demarcation can be seen readily with the unaided eye on a smooth transverse section. However, marks resembling the limits of annual growth do not indicate



F-20114

TRUNKS OF TWO TYPICAL TREES, SHOWING BUTTRESSES.





FIG. 2.—*Swietenia mahagoni*: a, Stem and leaf, natural size; b, flowering branch, natural size; c, flower, twice natural size.

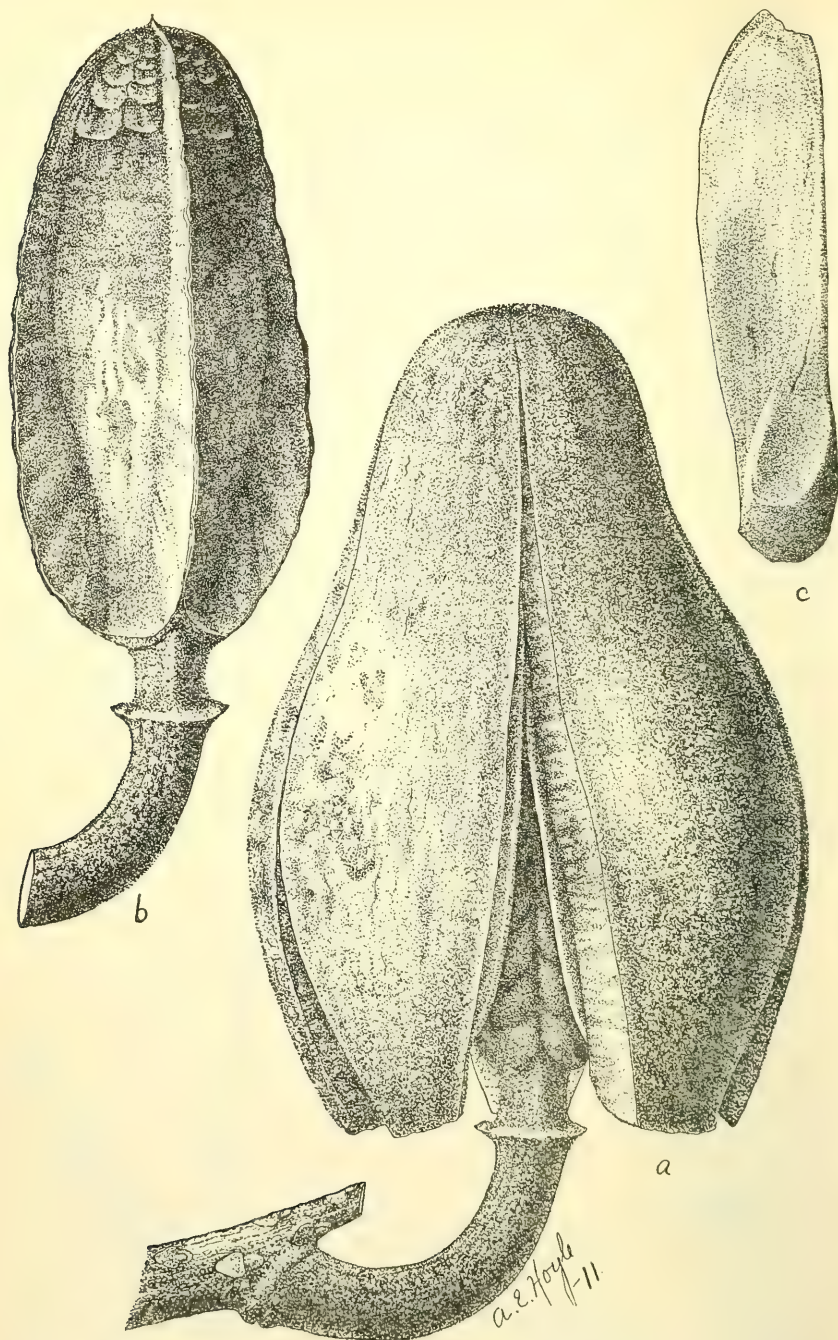


FIG. 3.—*Swietenia mahagoni*: a, A fruit; b, the axis of fruit, showing place of attachment of seeds at apex; c, winged seed. Two-thirds natural size.

the actual quantity of wood laid on during one year, but that of a much shorter or longer period. They may be due to drought, to defoliation, or to excessive heat or cold which interrupts growth activity for a short time. From this region northward the tree forms more and more distinct and at the same time much narrower annual rings of growth. The growth therefore is very slow, the vessels or water carriers are small, the wood fibers also are small and thick-walled, and as a result the wood is very heavy and hard.

Mahogany wood is diffuse porous; that is, the pores are distributed more or less uniformly throughout the wood. They usually occur singly, but may occur in radially disposed small groups of from two to four. Most of them are filled with tylosis, usually dark brown or reddish, but sometimes, as in Cuban and some Central American mahogany, white or nearly so.

The pith rays, from one to four cells wide, are the radially disposed rows of cells (parenchyma elements) seen with the unaided eye as faint lines in a smooth transverse section. They frequently have a slightly wavy course and bend around the vessels. In a tangential section they are often arranged in horizontal rows and are known as storied rays.

MINUTE CHARACTERS OF THE WOOD.

The quality and often the source of true mahogany may be determined by its minute structure. The length of the wood fibers varies according to the locality in which the tree grew. This variation in the fiber length is shown in Table IV. Microscopically considered, the wood of mahogany is made up of pores (or vessels), tracheids, wood-parenchyma fibers, wood fibers, and pith-ray cells. The minute characters of these elements are as follows:

Pores¹ in mahogany are rather large, with an average diameter of 0.15 millimeter, and together with accompanying parenchymatous elements often occupy the entire width of the wood ray; that is, the portion lying between two pith rays. The small pores are located near the periphery of the annual ring. These small vessels are composed of segments which often resemble tracheids in form. These segments, which can be seen in longitudinal sections or in macerated material, are from one to three times as long as wide (fig. 4, A). The openings in the horizontal partition walls of the larger vessels are round and simple throughout (fig. 4, A, *c*), while the openings on the smaller vessels are generally oval or elongated and placed obliquely. The vessel walls are furnished with numerous lenticular bordered pits (fig. 4, A, *d*), which occur in vertical rows where the

¹These elements are known as pores in transverse sections, and as vessels in longitudinal sections.

vessel is in contact with wood-parenchyma fibers, and in horizontal rows where it is in contact with pith rays, often giving the vessel a scalariform (ladder-like) appearance. The majority of vessels contain reddish-brown tyloses. These masses occur at regular inter-

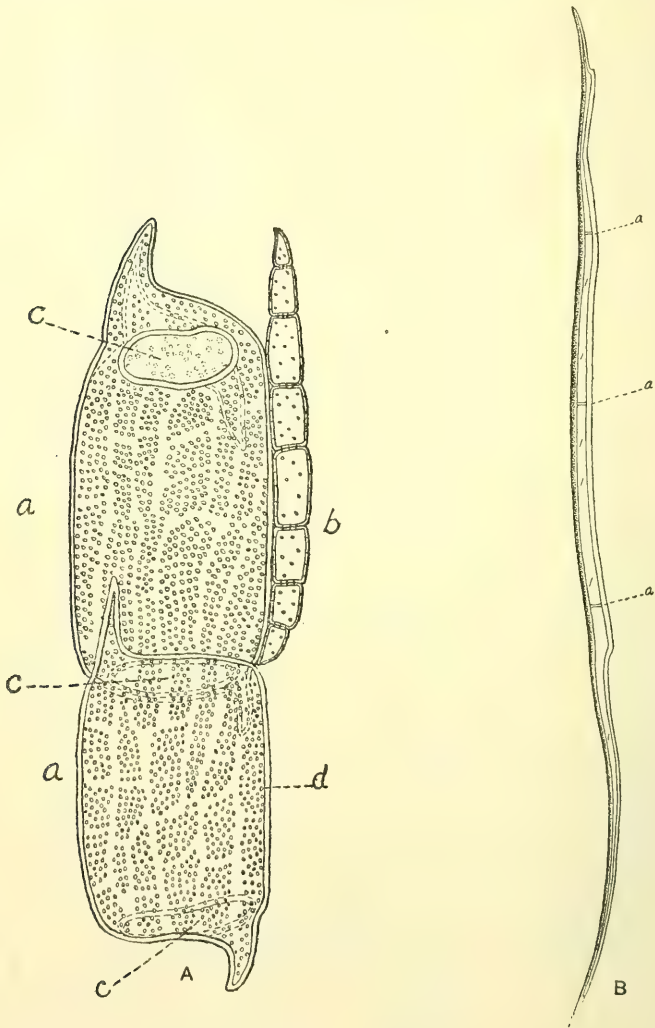


FIG. 4, A.—*a, a*, Two segments of a vessel, and *b*, wood-parenchyma fiber, both separated from the wood of *Swietenia mahagoni*; *c*, shows complete absorption of the partition walls of each vessel segment; *d*, small bordered pits. Magnified about 100 diameters.
 FIG. 4, B.—Wood fiber (separated) of *Swietenia mahagoni*, showing cross-partitions at *a*. Magnified about 100 diameters.

vals (longitudinal section), and often appear as minute partition walls within the vessels. They stain very readily with hæmatoxylin and dissolve under the action of Schultze's maceration mixture and

potassium and sodium hydroxides. The wood when boiled in a weak solution of the hydroxides yields a deep reddish-brown coloring matter.

Wood fibers occur usually in distinct radial rows, from a few to 12 or 15, between pith rays, and constitute the bulk of the wood. Near the pores this regular radial arrangement is often disturbed by their rapid growth. They are polygonal and have as a rule small lumina (cell cavities). They vary from 0.84 to 2.268, averaging 1.315 millimeters in length, and are rarely more than 0.02 millimeter in diameter. Wood fibers are often found that have delicate transverse partitions (fig. 4, B), a character that has been frequently observed in other woods belonging to this family of trees. True wood fibers are sometimes mistaken for wood-parenchyma fibers, but they may be distinguished from the latter by the very sharp-pointed ends and the minute, simple, slit-like pits. The fact that the wood fibers in mahogany are septate serves to distinguish true mahogany from a great many of its substitutes.

The cells in the outer part of the annual rings of growth are especially remarkable for their thickness and density. It is also noticeable that the cavities of the wood fibers in the early wood of samples from Florida and Cuba are larger than those formed later in the season. The reason for this appears to be that the fibers with wide cell cavities in the early wood serve as carriers of sap, and there is, therefore, no need of large vessels for this purpose in the late wood. This is evidently not the case in wood from British Honduras. In wood of the latter type, which forms no such large cells in the early wood, there seems to be greater need of large vessels throughout the entire seasonal or annual layer of growth in order to transport the large supply of water these trees require, because there is practically no cessation in vegetative activity throughout the growth period. The distribution of the large vessels is, therefore, regular throughout. In the wood with large vessels the fibers have thinner walls, and the quality of wood may be judged or predicted from such structural characteristics.

Wood-parenchyma fibers (fig. 4, A b) occur usually near the vessels and consist of from four to eight slightly elongated, thin-walled cells. In transverse section these cells are polygonal in form; in longitudinal section they are perpendicularly elongated and have small round or oval pits on their radial and tangential walls. Where they are in contact with vessels the pits are larger and not infrequently have a slight border. The individual cells contain an abundance of dense brown coloring matter similar to that found in pith-ray cells. A number of these fibers are made up of cubical cells with very thin walls, each cell being filled with a small crystal of calcium oxalate or calcium carbonate. These crystal-containing fibers are es-

pecially abundant in mahogany grown in dry, rocky soils as, for example, in Florida and Cuba.

Pith rays are from 1 to 4 cells in width, and from a few to 20 or more cells in height. The individual cells of the pith rays are generally rectangular in form and radially elongated, as seen in transverse and radial sections. The upper and lower rows (marginal cells), however, are elongated in the longitudinal direction. These marginal cells have thinner walls and less numerous pits than the other cells of the pith ray. Pith-ray cells have thin walls and possess only round simple pits. The pits, except where they are in contact with vessels, are large and simple, often slightly bordered. They are most numerous in the end walls. All the cells of the pith rays contain an abundance of reddish-brown coloring matter.

To determine the average length of the wood fibers of true mahogany and the effect of different climatic and soil conditions upon their length, samples of mahogany from the six regions were selected for examination under the compound microscope. The material was macerated by means of Schultze's maceration mixture, and the fibers measured. From these data averages were computed.

One hundred fiber measurements were taken from each individual block, and their averages computed, with the results shown in Table IV. The maximum and minimum lengths for each set of blocks are also given.

TABLE IV.—*Length of wood fibers of true mahogany from different localities, in millimeters.*

| Source of material. | Average. | Maximum. | Minimum. |
|---------------------|----------|----------|----------|
| Honduras..... | 1.747 | 2.268 | 1.218 |
| Venezuela..... | 1.324 | 1.638 | .882 |
| San Salvador..... | 1.271 | 1.722 | .882 |
| Cuba..... | 1.234 | 1.680 | .840 |
| Mexico..... | 1.176 | 1.470 | .882 |
| Florida..... | 1.136 | 1.428 | .840 |
| Average length..... | 1.315 | | |

WOOD CALLED "MAHOGANY."

The following cabinet woods resemble true mahogany in one or more characters, and on this account a good many, if not the majority, are marketed as mahogany of the particular region or country from which they are obtained. Some, however, occasionally come to the market under names of local origin.

FROM INDIA, CEYLON, ANDAMAN, EAST INDIES, AND BORNEO.

Madeira mahogany or Vinacito, *Persea indica* Spreng.

Mahogany or Andaman Padouk, *Pterocarpus dalbergioides* Roxb. and *Pterocarpus indicus* Willd.

Borneo mahogany, Palo Maria or Poon, *Calophyllum inophyllum* L.

East Indian mahogany, *Soymida febrifuga* A. Juss.

Indian mahogany or Toon, *Cedrela toona* L.

Indian mahogany, *Melia composita* Willd.

Mahogany, Jackwood, or Orangewood, *Artocarpus integrifolia* L.

FROM AFRICA.

African mahogany, *Khaya grandifolia* Stapf.

African mahogany or Ibeka, *Khaya klainei* Pierre and *Khaya euryphylla* Harms.

African mahogany, *Pseudocedrela utilis* D. & S.

African mahogany, *Ricinodendron africanus* Muell.

African mahogany, Kino, Boi, or Okwen, *Ricinodendron hendelotti* Pierre.

African mahogany or Ocapao, *Azelia africana* S.

African mahogany or Cedar, *Trichilia pricuriana* A. Juss.

Agonokwi or Emido, *Mimusops multinervis* Baker.

Benin or Gold Coast mahogany, *Khaya grandis* Stapf.

Cail-Cedra or un bel Acajou, *Entandrophragma candolleana* De Will.

Dita or Detarr mahogany, *Detarium senegalense* Gmel.

Ory Zone mahogany or Cedar,¹ *Pseudocedrela kotschy* (Schweinf.) Harms.

Gambia or Senegal mahogany, Cailcedra, Hie, Jallow, Dubina, or Oganwo, *Khaya senegalensis* A. Juss.

Gogo or African mahogany, *Carapa gogo* A. Chev.

Konta, Bendiguri, or Aligna, *Azelia bracteata* Vog.

Natal mahogany, *Kiggelaria drageana* Turez.

Nigeria mahogany, *Khaya purchii* Stapf.

Obega or Gaboon mahogany, *Entandrophragma pierrei* Chevalier.

Okume, African cedar, or Libreville mahogany, *Boswellia klaineana*.

Punkwa and Tiama-tiama, *Pseudocedrela cylindrical* D. & S.

Quibaba da Questa, *Entandrophragma angolense* C. DC.

Sapeli, Ikwapelo, or Azore, *Entandrophragma candollei* Harms.

West African mahogany or cedar, *Pseudocedrela excelsa* D. & S.

White mahogany, *Piptadenia africana* Hook.

White mahogany or Incense tree, *Santiriopsis klainei* Pierre.

White mahogany or Quibaba da Mussangue, *Khaya anthotheca* C. DC.

FROM AUSTRALIA.

Australian mahogany, *Dysoxylon fraserianum* Benth.

Bastard mahogany, *Eucalyptus botryoides* Sm.

Red mahogany, *Eucalyptus resinifera* Sm.

Red mahogany or Tallow wood, *Eucalyptus microcorys* F. v. M.

Swamp mahogany, *Tristania laurina* R. Br.

Swamp mahogany, *Eucalyptus botryoides* Sm.

White mahogany, *Eucalyptus robusta*.

FROM PHILIPPINE ISLANDS.

Lumbayao mahogany, *Tarrietia sylvatica* (Vid.) Merr, or *javonica* Bl.

Padouk, Red narra or Tenasserim mahogany, *Pterocarpus indicus* Willd.

Philippine mahogany, Tanguile, or Balacbaccan, *Shorea polysperma* (Blanco) Merrill.

Philippine mahogany, Mangachapuy, or Red lauan, *Shorea negrosensis* Foxw.

FROM UNITED STATES AND CANADA.

Coffeetree or mahogany, *Gymnocladus dioica* (L.) Koch.

Red gum, *Liquidambar styraciflua* Linn.

¹ This wood is very seldom exported on account of the small size of the tree. Locally the wood is highly esteemed and is preferred to that of *Azelia africana*, which is a splendid wood and is used extensively.

Mahogany, Yellow birch, or Mountain birch, *Betula lutea* Michx. f.
 Mountain birch or Sweet birch, *Betula lenta* L.
 Western sumach, *Rhus integrifolia* (Nutt.) Benth. & Hook.
 Mountain mahogany, *Cercocarpus ledifolius* Nutt.
 Valley mahogany, *Cercocarpus parvifolius* Nutt.

FROM MEXICO, CENTRAL AMERICA, AND WEST INDIES.

Indian mahogany or Spanish cedar, *Cedrela odorata* L.
 Madeira (mahogany), *Tamarindus indicus* L.
 Horseflesh mahogany, *Caesalpinia* sp.
 Espave mahogany, *Anacardium rhinocarpus* DC.
 White mahogany or Jenicero, *Tabebuia donnell-smithii* Rose.
 Balata, Bully, or Bulletwood, *Mimusops globosa* Gaertner.
 Sabicu (Bahama), *Lysiloma sabicu* Benth.
 Sabicu Cuban), *Pithecolobium arboreum* (L.) Urb.
 Santa maria, *Calophyllum calaba* Jacq.

FROM SOUTH AMERICA.

Horseflesh mahogany, *Swartzia tomentosa* D. C.
 Colombian mahogany, *Cariniana pyriformis* Miers.
 Demerara mahogany, Crabwood, or Carapa, *Carapa guianensis* Aubl.
 Cumussin, *Carapa grandiflora* Mart.
 Jacariuba, *Calophyllum brasiliense* Camb.

Of the 61 species listed, 24 belong to the same family as true mahogany, but none to the same genus—*Swietenia*. The next most important family group is *Leguminosae*, of which 12 species are represented in the foregoing list. Unfortunately, not all of the technical names of the trees can be given, since in some localities, especially in West Africa, the identity of a good many has not yet been determined. In fact, the actual source of a number of "mahoganies" from West Africa is unknown except to a few native merchants who control the output. The following list shows the different families to which the so-called "mahoganies" of commerce belong:

| Family. | Genera. | Species. |
|--|---------|----------|
| Meliaceae (Mahogany, Spanish cedar)..... | 10 | 24 |
| Leguminosae (Locust, Judas tree)..... | 10 | 12 |
| Myrtaceae (Eucalyptus, pimento)..... | 2 | 6 |
| Anacardiaceae (Sumach)..... | 2 | 2 |
| Burseraceae (Gumbo limbo, or West Indian birch)..... | 2 | 2 |
| Rosaceae (Apple, pear)..... | 2 | 2 |
| Sapotaceae (Chicle tree, sapodilla)..... | 2 | 2 |
| Euphorbiaceae (Castor oil plant, crotons)..... | 1 | 2 |
| Storculiaceae (Cocoa, cola)..... | 1 | 2 |
| Dipterocarpaceae (Borneo camphor tree)..... | 1 | 2 |
| Betulaceae (Birch, alder)..... | 1 | 2 |
| Moraceae (Mulberry, osage orange)..... | 1 | 1 |
| Lauraceae (Sassafras, red bay)..... | 1 | 1 |
| Guttiferæ (St. John's wort, palo maria)..... | 1 | 3 |
| Flacourtiaceae (Arnotto)..... | 1 | 1 |
| Pernoniaceae (Catalpa, trumpet creeper)..... | 1 | 1 |
| Pecyhtaceae (Monkey-pod tree, Brazil-nut tree)..... | 1 | 1 |
| Hamamelidaceae (Red gum)..... | 1 | 1 |
| | 41 | 67 |

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REFORESTATION ON THE NATIONAL FORESTS.

By C. R. TILLOTSON, *Forest Examiner.*

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INTRODUCTION.

The National Forests are scattered from Alaska to Porto Rico and contain within their boundaries all sorts of timberlands, from those which produce only cordwood to those which support the finest and most valuable stands of timber in the world. Sometimes natural regeneration of the forest fails or a forest not yet producing seed needs to be increased in density. There are also in the National Forests about 5,600,000 acres now bearing little or no tree growth which are capable of producing valuable timber and are suitable for no other purpose. It is the object of reforestation to improve the stands which are too thin and to make the bare lands productive. Reforestation operations on the National Forests now cover from twelve to fifteen thousand acres yearly.

NOTE.—This bulletin supersedes Forest Service Bulletin 98, "Reforestation on the National Forests," by W. T. Cox, on which the material relating to seed collecting and direct seeding is largely based. It represents the results of the study and experience of many different members of the Forest Service. The author's part has been to compile, weigh, and harmonize these results and to present the reforestation work of the Forest Service as a whole.

The greater portion of the area which it seems advisable to reforest consists of old burns, where recurring fires have completely ruined the former forest and have left a scanty, sterile, and dried-out soil, often littered with charred down timber and stumps. Some of these old burns are grown up to brush, some to fern, and some to grass and fireweed. Many have been badly eroded; and there are large areas where most of the vegetable soil has been burned. Among the easiest to reforest are those which have recently suffered from light fires, so that the mineral soil is exposed, but which are not so badly eroded or grown up to brush as to make the establishment of tree growth very difficult.

REFORESTATION AN ESSENTIAL FEATURE OF NATIONAL FOREST ADMINISTRATION.

The two chief objects of the National Forests are the production of timber and the protection of water sources. The timberlands of the National Forests are now producing from five to six billion board feet of wood a year. The complete restocking of the areas now denuded or sparsely timbered will increase the annual production of wood at least 3,000,000,000 feet. Probably still greater advantages will be secured eventually through improved conditions for stream-flow on many watersheds. This is a public benefit of immense importance because of its relation to the supply of water for cities and towns, the protection of water sources for irrigation and power, and the navigation of large streams. Restocking can be brought about in part by the protection of the forests from fire, which permits the natural extension of tree growth. The rest can be accomplished only by forest planting.

In selecting sites for artificial reforestation preference is usually given in the following order: First, watersheds of streams important for irrigation and municipal water supply, such as those which supply water to Colorado Springs and Salt Lake City; second, lands which will produce heavy stands of quick-growing trees of high commercial value, such as those in northern Idaho and western Washington; third, regions where the supply of timber is limited and more wood is needed for local uses, as in western North and South Dakota; and fourth, sites which offer good opportunities for object lessons in the practice of forestry, such as the sand hills of western Nebraska (Pl. I), where there is practically no natural woodland, and the inferior sandy lands of the Lake States, where the original forest wealth has been largely destroyed by cutting and fire. Some areas combine several advantages. For instance, a burned-over tract may be suitable for sowing to some rapid-growing timber species and may

be so situated that the plantation will serve as an excellent object lesson.

The economic importance of field planting or sowing, the expense attending it, the even greater proportionate expense of replanting or resowing parts of areas where the first operation failed, and the high percentage of mortality which is almost sure to attend ill-advised and hasty work have led to two stages in reforestation work on the National Forests; first, experiments conducted on a small scale; and, second, extensive field operations. Successful field planting or sowing on a large scale is not a simple operation. The task of planting or sowing so many acres to forest trees or seed in a given period of time is merely a matter of providing the seed or nursery stock and employing a crew of sufficient size, but the success of the operation depends on much more than this. The object of experimental planting and sowing is to determine the factors which make for success or failure. These in turn serve as a guide for reforestation operations on a large scale. Experimental planting or sowing is usually intensive and necessarily expensive. Practical reforestation on a large scale takes advantage of the facts learned through experimental work, and the foremost consideration is to make the costs reasonable and yet secure success.

COLLECTION OF SEED.

SEED CROPS.

All planting and sowing must begin with the collection of seed. Trees, unlike some other plants, do not bear a good crop of seed every year. Conifers in particular are very irregular about this. A few cones are produced every year, but with most species it is only at intervals of from two to five years, or more, varying with the species and the climatic conditions, that a heavy crop occurs. Years when seed of any species is produced in abundance are known as "seed years" for that species, and the intervening years are called "off years." During "off years" seed is produced only in small quantities; it is difficult to obtain because of the concentrated demand for it by rodents and birds, and there is a smaller yield per bushel of cones.

In a "seed year" the seed crop of any species is usually abundant throughout the tree's range, though much better in some places than in others. Even during an "off year" a species may produce somewhere within its range a fair crop over a limited territory. The season of 1910 was an "off year" for both Douglas fir and western yellow pine, the two most important trees of the West, yet cones of sufficient quantity were collected in widely separated localities to furnish 30 tons of clean seed of these species. Studies made to de-

termine what constitutes a good crop for different species have given the following figures:¹

TABLE 1.—*Amount of seed per acre produced by different species.*

| Species. | Trees
per acre. ¹ | Cones
per tree. | Seeds per
bushel
cones. | Seed
per acre. |
|--------------------------|---------------------------------|--------------------|-------------------------------|--------------------|
| | | <i>Bushels.</i> | <i>Pounds.</i> | <i>Pounds.</i> |
| Douglas fir..... | 10 | 3.50 | 1.00 | 35.00 |
| Western yellow pine..... | 5 | 4.00 | 1.50 | 30.00 |
| Lodgepole pine..... | 40 | .50 | .40 | 8.00 |
| White pine..... | 7 | 1.00 | 1.00 | 7.00 |
| Red pine..... | 5 | .80 | 1.00 | 4.00 |
| Engelmann spruce..... | 12 | 1.25 | .80 | 12.00 |
| Sugar pine..... | 8 | 7.00 | 1.60 | ² 89.60 |

¹ Bearing seed in appreciable quantities.

² The sugar pine seed is large, so that this weight does not indicate a greater number of seed per acre than is produced by some of the other species.

GATHERING THE SEED.

Before beginning the actual work of collecting the seed of any species, information regarding the seed crop in various portions of the tree's range must be obtained. Knowledge of the relative abundance of cones and the possibility of economically collecting seed in the different localities makes it possible to concentrate the work where the best results can be had at the least expense. Small, scattered operations are the most costly.

Cones of most of the pines take two years to mature. Those of some of the junipers and cypresses also take two years, and a few require three years. It is often possible, therefore, to predict a crop of any of these species in advance. Other conifers ripen their cones in one season.

Careful examination of both the cones and the seed is necessary to determine when collecting should begin, because cones ripen at different times in different parts of a tree's range and at different altitudes and localities in the same region. The external appearance of the cone is not a sufficient indication of the condition of the seed; a number of cones should be cut open and the seed themselves examined. So long as the seed are soft and milky they are immature. When the squirrels begin to cut off cones for storing, collecting should begin at once. Hard frosts, followed by warm days, hasten the ripening and opening of cones, and for most species the period of collection is short if the cones are taken directly from the trees. Therefore, when once collection is begun it should be pushed forward with all possible haste.

Cones are collected from felled trees, from standing trees, and from squirrel hoards. Where logging is going on it is often pos-



F-22221A

FIG. 1.—JACK PINE PLANTED ON NEBRASKA FOREST, APRIL, 1911. PHOTOGRAPHED MAY, 1914.



F-22216A

FIG. 2.—PORTABLE FIELD CAMP ON NEBRASKA FOREST PROVIDING ACCOMMODATIONS FOR 34 HORSES AND 50 MEN. THIS CAMP IS MOVED EVERY TWO YEARS.



FIG. 1.—DRYING CONES IN THE SUN.

F-13342A



FIG. 2.—BINS FOR STORING CONES. BITTERROOT NATIONAL FOREST.

F-99771

sible to pick the cones from the felled trees and from the ground after the brush is piled. This is a good, rapid method, provided a large number of trees are felled each day.

In collecting from standing trees it may or may not be necessary to climb them. Cones can often be stripped from short-limbed trees by hand or by the use of sharp-edged hooks fastened to poles. When climbing is necessary, the cones are stripped or picked off by hand or by means of similar hooks with short handles. It is best to begin work at the top of the tree, because the branches are shorter there, and the cones can more easily be seen. Occasionally it is advisable to cut down heavily fruited trees, but only when the tree itself can be utilized.

Squirrel caches are usually by far the best places from which to obtain cones. Pine squirrels collect large quantities, and chipmunks and mice lay by smaller stores. These rodents do not put by seed sufficient for the winter only, but collect as long as the supply lasts and the weather permits. In consequence they frequently lay by quantities out of proportion to their need.

The small red squirrels are the greatest collectors; and it is not uncommon to find in one of their caches from 8 to 12 bushels of good cones, though the average quantity is about 2 bushels. The caches are sometimes buried at a considerable depth near old rotten logs, in springy places and muck, in duff, under bushes and felled tree tops, along streams, and beneath overhanging stream banks. Their presence is often indicated by heaps of cone scales and chips where the squirrels have been feeding. Sometimes, however, they are carefully covered with leaves and humus, making it difficult to locate them, though the squirrels' well-beaten trails often guide the collector. The squirrels do not confine their collecting to a few species, but appear to relish a large number. Some of the species of cones which are often obtained from caches are Douglas fir, Engelmann spruce, western yellow pine, lodgepole pine, and western white pine. Usually the cones of but one species are found in a single cache. In collecting from squirrels' hoards it is well to have a pack horse for immediate transportation; for if cones are dug out and left loose or in sacks on the ground for any length of time they will be carried away and cached again by the industrious animals.

Collecting from squirrel hoards has important advantages over the other methods; it is usually cheaper; it can be carried on after the cones on the trees are open; and a high grade of cones is obtained. In one instance 610 bushels of lodgepole-pine cones were collected from squirrel caches on the Targhee National Forest, at an average cost of 18 cents a bushel, one man collecting $16\frac{1}{2}$ bushels a day. During the fall of 1908, 1,137 bushels of yellow-pine cones were col-

lected from caches on the Boise National Forest after the cones on the trees had opened.

Burlap sacks with a capacity of about 2 bushels of cones have been found very suitable for collecting operations. After sacking, the cones should be put in a cool, dry place to prevent their opening and the escape of the seed, and to prevent their molding, which results in deterioration of the seed.

DRYING THE CONES.

It is exceedingly important that the cones be air-dried promptly after collection; and it is the usual practice to extract the seed soon after collection is completed. If the cones are placed in well ventilated bins and thus kept dry, immediate extraction is unnecessary. It often happens that collecting and extracting can be carried on simultaneously. Promptness is often necessary to prevent molding and heating of the cones. Good drying weather does not continue in most parts of the West very long after the cones are ripe, and fresh seed is desirable for fall sowing or nursery operations.

DRYING WITH NATURAL HEAT.

The plan commonly followed in drying western yellow pine, Douglas fir, and spruce cones is to spread the cones on canvas sheets of 8 oz. material, 12 feet by 14 feet in size, to dry in the sun (Pl. II, fig. 1). Ordinarily 1 bushel of cones should be spread out to occupy 20 square feet of canvas. This is usually much cheaper than transporting the cones to the drying house and opening them by artificial heat. Furthermore, experiments with western yellow-pine seed at the Priest River Forest Experiment Station show that the viability of seed extracted without artificial heat is much greater than of that extracted with it.

The time required for cones to open varies greatly with climatic conditions and somewhat with different species. A succession of clear, sunny days and frosty nights, with brisk winds, will open cones very rapidly. In such weather mature western yellow-pine cones open in from three to five days. Under ordinary weather conditions, from 4 to 10 days are required, and in damp, stormy weather, often as many as 15 days. Douglas fir and Engelmann spruce usually require a day or two longer under the same conditions. Lodgepole pine takes so much longer that sun drying is seldom attempted. Cones picked early in the season before they are thoroughly ripe open much more slowly than those picked later. If the drying is likely to continue until the ground becomes cold and wet, it is well to keep the canvas off the ground by means of brush or a slightly raised platform. At night and during damp weather the canvas sheets should be drawn up by the

corners and either tied in bundles or one side thrown over the cones. When this is done, the cones retain to some extent the heat absorbed during the hours of sunlight, they are not wet by night dews, and they are somewhat protected against nocturnal rodents.

On the Bitterroot National Forest, western yellow-pine cones have been very successfully dried and opened in bins of the type shown in Plate II, fig. 2. These are 16 feet wide by 14 feet deep and are covered, in sections of three, by a single tin roof. There are 8 floors spaced 18 inches apart in each bin. The bottom floor is built to retain any seed which may fall from the cones, and is of solid matched boards. The other floors are of loose 6-inch boards, which can be removed successively from the lowest to the highest. This allows all the cones to fall to the bottom floor, from which they are easily removed during the course of the extracting operations. The side walls consist of successive pairs of 6-inch boards, each pair being separated from the next by a 6-inch open space. The lower edge of each pair is flush with one set of floor boards. The bins are, accordingly, a series of boxes inclosed on the sides for only two-thirds of their height. Each bin is divided into four compartments 4 feet wide and 14 feet deep, and the total capacity of the four compartments is 640 bushels of unopened Idaho western yellow-pine cones. The bin is designed to secure as much free circulation of air over and around the cones as possible and to protect them from rain or snow. Canvas sheets are used to protect the walls during driving storms. Western yellow-pine cones open well in the bins without artificial heat in from four to six weeks, the time required depending upon the weather.

DRYING WITH ARTIFICIAL HEAT.

The cones of lodgepole pine must always be opened by means of artificial heat. It is necessary to open those of other species by this method only when weather conditions are unfavorable for drying by natural heat. Artificial drying is a quicker method than the other and is not dependent on the weather; but it is more difficult and more expensive, and ordinarily does not yield as good seed.

DRYING PLANTS.

Permanent type.—Some of the artificial drying is done at large, fully equipped, permanent plants, to which cones are shipped from a large area (Pl. III, fig. 1). At these plants the cones are put on cars, which are run into kilns resembling in construction those in use at hardwood distillation plants (Pl. III, fig. 2). Here seed extraction is reduced to a science and is done at a low cost, provided

large quantities of cones have been gathered. There are smaller drying plants designed for use only on the National Forest where they are located. These are quite simple in their plan and of relatively cheap construction.

Figure 1 shows the plan of a small cone-drying plant on the Arapaho National Forest, Colo. It has been used exclusively for the extraction of lodgepole-pine seed and has proved quite satisfactory. The pine cones are collected in October and held in a storage bin from 12 to 15 months before the seed is extracted. This bin holds approximately 6,000 bushels of cones and is divided into several compartments. A passageway between these permits the removal of the cones to the drying room. The sides and end of the bin are constructed of 4-inch boards spaced a short distance apart to facilitate the preliminary air-drying of the cones. The kiln or drying room proper is constructed within the main building and is located directly over the furnace in the basement. This kiln is 11 feet by 9 feet in size, outside dimensions, and is made as tight as possible.

When the cones are to be opened, they are placed in shallow trays 2 feet 10 inches by 7 feet in size, which have one-fourth inch mesh hardware cloth bottoms. The capacity of each tray is 1 bushel of unopened cones. The trays are braced at the four corners on the bottom with 2-inch pieces of wood, so that when they are piled in tiers the air may circulate freely between them. Three tiers of trays, 12 per tier, constitute a charge for the kiln. The trays are loaded on a truck, wheeled to the kiln door, and in one lot shoved into the kiln on rolls. Each charge of cones is dried for eight hours, and the plant is run continuously, except Sunday, in three eight-hour shifts daily.

The kiln is heated by means of four hot-air flues coming from the furnace and terminating at the floor of the kiln. Opened cones exclusively are used for fuel. When removed from the kiln, the cones are placed in a large hopper and gradually fed into the drum of the "shaker." As the shaker revolves, the seed are separated from the cones and fall upon a canvas spread on the floor. The open cones from which the seed has fallen pass through the shaker and out the open end down a chute to the furnace room.

The capacity of this plant is 108 bushels of cones, or about 40 to 45 pounds of seed, per day.

Temporary type.—Where there is only a relatively small quantity of cones, resort is often had to temporary plants which are handled by less experienced men with simple appliances. The first essential in such cases is some sort of shelter which will protect the cones from weather and be sufficiently tight so that the temperature can be raised to at least 110° F. An empty room in a cabin may serve the purpose and often makes as satisfactory a substitute for a regular kiln as can be obtained. It must have tight walls and plenty of space

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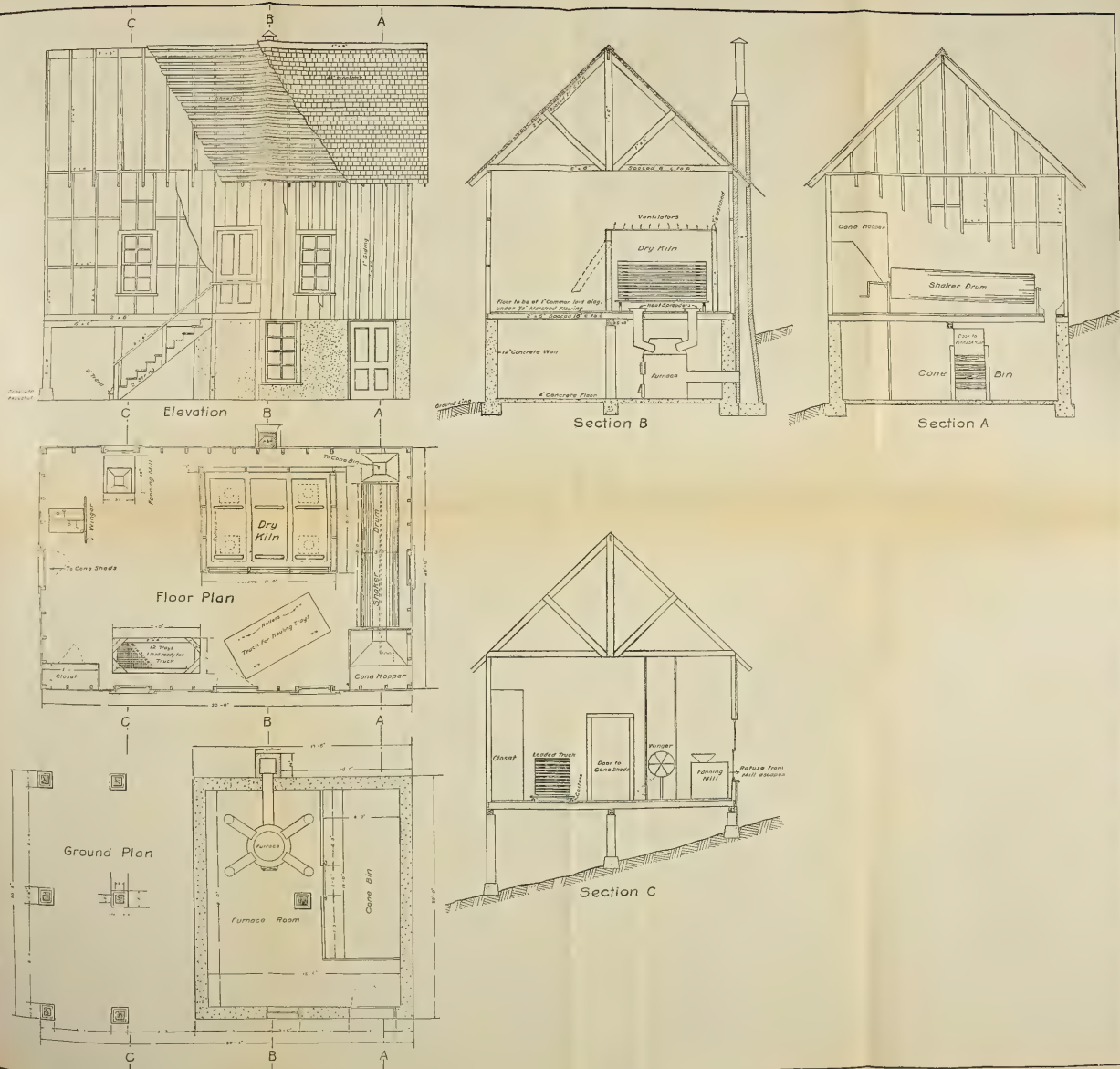
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for a stove and for trays around the sides. Often one room of a cabin is used for drying and another for storing and extracting.

Large tents with high walls make fair dry rooms; 12 by 16 foot or 16 by 20 foot tents, with 5 or 6 foot walls, may be used, but the larger tents have given the most satisfactory results. Drying is more difficult in tents than in buildings, but the tents have the great advantage of being readily transported from place to place where cones are collected. Ordinarily, the largest tents are used for drying and smaller tents for storing and extracting.

Small, temporary drying rooms are almost invariably heated by stoves. In buildings, box stoves equipped with drums have been generally used with satisfactory results. In tents, low, conical stoves have been more frequently used because they are cheap and easily put up. They require constant attention, however, and empty cones will not burn well in them. These are serious drawbacks, and the use of box stoves with drums is preferable.

The cones are usually spread in trays arranged in racks along the sides of the room or tent. Trays are generally made of 2 by 4 inch material, and vary in size from 2 by 3 to 3 by 4 feet. The larger trays are difficult to handle, especially where space is limited, and are used only with light cones. The bottom of the tray is wire netting, usually with a one-half inch mesh for lodgepole pine and a three-fourths inch mesh for larger cones. A tray space of 12 square feet holds approximately 1 bushel of cones spread thinly.

Cones may also be spread on pieces of wire netting stretched horizontally between racks at intervals of 6 or 8 inches with a vertical strip at each end to prevent their falling on the floor when raked. Handling the cones is more difficult with this method, and the apparatus is less easily transported from one place to another. With either method a strip of canvas is spread on the floor to catch the seeds as they fall through the netting, unless the floor is so smooth that seed can readily be swept from it without the use of canvas. It is essential that the trays be far enough apart, commonly from 6 to 8 inches, to permit ample circulation of air. There should be a liberal supply of high registering thermometers to keep an accurate record of the temperature in different parts of the drying room.

On account of the high temperature and dry air prevailing in the kiln room, extreme precaution must be taken to prevent fire. Where water pressure is available, a hose should always be connected and ready for use. Chemical fire extinguishers should be secured as additional safeguards. If neither of these measures is practicable, several buckets should be kept filled with water, to be instantly available.

Heating.—One of the most difficult problems in running an improvised kiln is to maintain a constant supply of heat and distribute it evenly through all parts of the drying room. The first step should

be to make the room, whether in a building or tent, as tight as possible, except for the openings required for ventilation. All chinks should be closed completely. Wherever practicable as hot a fire should be kept up at night as during the day. This is particularly necessary in a tent, where any dying down of the fire at night causes the air to cool rapidly, with consequent delay and loss of time and labor.

The stove is usually placed in the center of the room and approximately level with the lowest tiers of trays. This results in much slower drying of the cones which are near the bottom of the room and at a distance from the stove. Attempts have been made to obviate this difficulty by dividing the stovepipe into sections and carrying it through as much of the room as possible, but without complete success. Better drying is secured in the farther ends of the room, but the bottom remains much cooler than the top. This difference is especially marked in tents, where cold air constantly passes in under the walls. With only one stove even distribution of heat is impossible. With stoves set at opposite ends of the tent and connected by a single stovepipe conditions are but little better. In one instance where this arrangement was used a difference of from 20° to 30° F. was found in the temperature of the air at the highest and lowest trays in a six-tier stack.

One method of hastening the opening of the cones in the lower trays is to raise them as the drying proceeds and the cones in the upper trays are removed. This, however, requires additional handling and loss of time. A better method, wherever space is available, is to place the lowest tier of trays somewhat above the stove. Room for air circulation is essential. The tiers of trays should be at least 6 inches apart vertically, preferably 8 inches, and the same distance from the walls.

The best method of securing even distribution of heat, although not always practicable, is to have the drying room heated from below. If conditions permit, an excavation should be made under the building and the stove placed below the floor. This not only heats the room above more evenly, but furnishes additional space for spreading cones. The stovepipes should pass through as many parts of the dry room as possible. Still better results are obtained if hot-air pipes can be conducted from the drum of the stove into the room above, and even more heat can be made available by inclosing the stovepipes in jackets, which need not extend farther than the openings where the pipes pierce the floor.

Maximum temperatures and duration of heating.—The degree of heat and the length of time required to open cones vary somewhat with different species, but still more with the conditions under

which the drying is done. In a well-equipped plant drying may be finished in less than half the time required in a tent, even with the same temperature. It is therefore impossible to cite average figures of general application. Ordinarily, the higher the temperature the quicker the drying can be accomplished. Dry heat, however, is more effective than moist heat, and heat that is too intense is very apt to impair the fertility of the seed. This is particularly true of intense moist heat. Often this injury to seed is not appreciated at the time, since the deterioration does not become apparent until several months later.

The maximum temperature which should ordinarily be applied to all species except lodgepole pine is 120° F. This can be raised safely to 130° F. if the air is dry and good ventilation provided. Lodgepole-pine cones should not as a rule be subjected to a temperature of more than 140° F., although this can be raised safely to 150° F. under favorable conditions. Lodgepole-pine cones are hardest to open; then come, in order, western white pine, western yellow pine, Engelmann spruce, and Douglas fir. Douglas fir cones can often be dried satisfactorily at a temperature of 110° F.

Assuming that the cones are mature and moderately dry when put into the kiln and that the room is evenly heated and well ventilated, lodgepole-pine cones should be thoroughly dried in from 8 to 10 hours at a constant temperature of 140° F. and other species in from 10 to 15 hours at a constant temperature of 120° F. Under less favorable conditions these periods may be greatly increased. In one instance lodgepole-pine cones dried in a tent at 140° F. took 44 hours to open. The difference was due mainly to uneven distribution and loss of heat in the tent. Preliminary drying of the cones for a few hours at from 80° to 100° F. has been found an advantage. Opening will also be hastened by spreading the cones thinly in the trays and stirring them frequently to make the drying more uniform.

Ventilation.—The proper ventilation of drying rooms, while less difficult than the even distribution of heat, is fully as important. All undried cones contain some moisture. As this is driven off the air becomes more and more saturated. Saturated air not only prevents rapid drying of the cones, but may injure the seed embryos. German experiments indicate that damp, cold air is much more harmful to seeds than dry, warm air. Some method of ventilation (letting in fresh, dry air and letting out moist air) is, therefore, essential.

The method usually employed is to insert one or two ventilators in the roof of the building or tent and also in openings near the floor for the entrance of fresh air. The amount of air taken in and let out can be regulated by adjustment of the ventilators. Tents are

usually so open at the bottom that it is not necessary to make special provision for fresh air. Where the drying room is heated from below fresh air can be admitted through dampers or ventilators in the jacket surrounding the stove. Vents to maintain circulation should also be provided in the roof of the drying room.

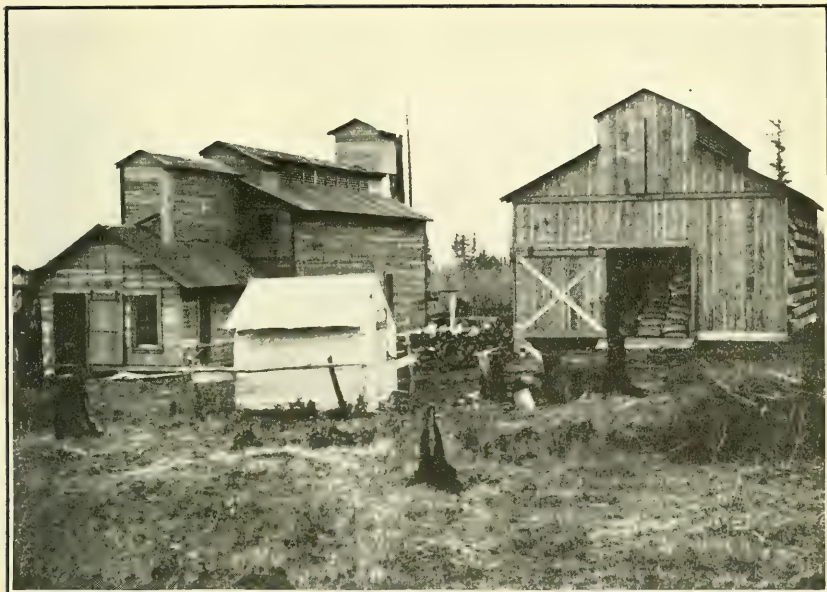
Though they are usually the best that are practicable, these methods of ventilation are necessarily crude and wasteful. As the air cools and absorbs moisture it becomes heavier and sinks to the floor. Vents in the roof carry off much of the hot, dry, light air which should be retained. A certain amount of heavy, moist air is, however, carried out with the current, and the circulation of air, so essential to drying the cones, is maintained.

An improved method removes the saturated air directly from the floor by pipe ventilators extending from the floor through the roof. In one kiln fresh air is admitted directly under a small box stove with a heating drum placed near the center of the room. As this air becomes heated it rises to the ceiling, where it spreads to the side walls, and, cooling slightly, descends in a steady stream over the cones. The trays thus catch the descending current of hot air, which flows over them. They are slightly tilted toward the center of the room, so that as the air cools and absorbs moisture from the cones it runs off the lower edge of the trays like water from a roof. The saturated air is sucked up by pipe ventilators having inlets at the floor level and passing through the roof.

WETTING CONES.

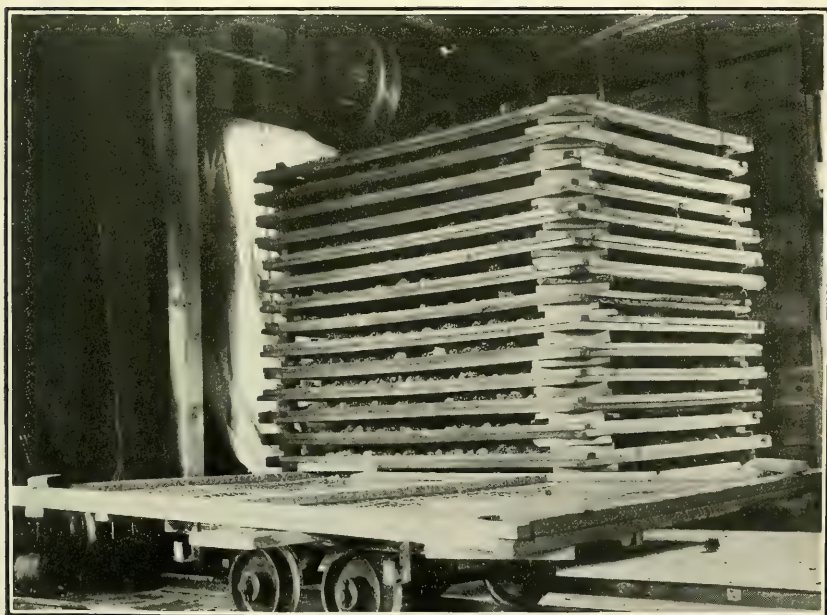
Wetting cones before drying apparently does more harm than good with any species except lodgepole pine. Lodgepole-pine cones dipped in very hot water for not over one minute have, in some cases, been found to open more readily and to give a higher yield than unmoistened cones. This treatment, however, should be applied only to very tight cones and should not be of sufficient duration to add appreciably to their water content. Its only advantage is that it loosens the sealed tips of the cone scales. Experiments have also shown that live steam applied under a pressure of one-half pound for 30 seconds assists in opening cones without impairing the fertility of the seed. Such treatment, however, is possible only at fully equipped extracting plants.

Even with lodgepole pine a preliminary wetting is not essential, and good results are obtained without it. Continued soaking of cones has almost uniformly lessened the ease of extraction and injured the seed. As a general rule, the cones should be as dry as possible before they are put into the kiln. Preliminary drying in the open or in well-ventilated storerooms will hasten opening after artificial heat is applied.



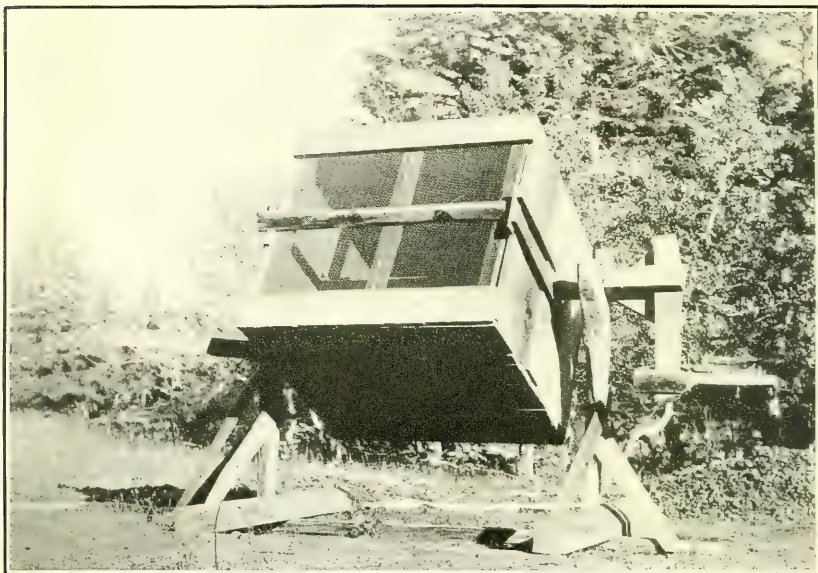
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FIG. 1.—LARGE SEED-EXTRACTING PLANT OF THE KILN TYPE AT WYETH, OREG.



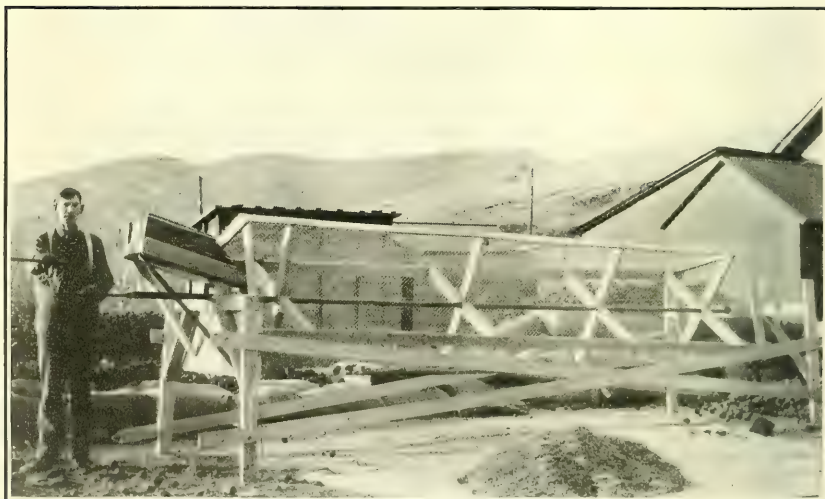
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FIG. 2.—CAR OF CONES REMOVED FROM THE DRY KILN AT A LARGE PERMANENT SEED-EXTRACTING PLANT.



F-9328

FIG. 1.—CHURN FOR REMOVING SEED FROM OPENED CONES.



F-94486

FIG. 2.—CHURN FOR REMOVING SEED FROM OPENED CONES.

EXTRACTING THE SEED.¹

After the cones have been thoroughly dried, the next step is to extract the seed. Merely to rake over the cones as they are drying in the sun or kiln is the simplest but least efficient method. It is most successful with western yellow pine, but even with this species better results can usually be obtained by shaking. The practice of placing cones in sacks and beating them with clubs to loosen the seed has also proved unsatisfactory. It requires too much time and yields only a little additional seed, which is apt to be of poor quality.

CONE SHAKERS.

To secure the maximum amount of seed, therefore, some method of shaking to release the seed from the opened cones must be used in nearly every case. Several kinds of cone shakers have been devised by members of the Forest Service. One in common use is made from a large dry-goods box, about 4 by 3 feet, provided at one end with a door made of slats so spaced as to permit only the closed cones to fall through. (Pl. IV, fig. 1.) This door is fitted also with a removable wire screen of such sized mesh as to permit only the seed to escape, ordinarily $\frac{1}{2}$ inch. The box is built on a pole as an axis and swung between two trees, or else mounted on a windlass. By a crank attached to one end of the axis the apparatus may be revolved and the seed loosened. SlatS nailed lengthwise inside the box, or loose blocks of wood placed in the box with the cones, increase the jarring effect. After the seed has escaped to a sheet of canvas placed beneath the shaker, the screen should be removed and shaking continued in order to separate the still closed cones from the larger sized open ones. The closed cones can then be returned to the house for further drying.

The cone shaker shown in Plate IV, figure 2, is a modification of the common potato sorter. It has been used extensively for yellow-pine cones, and, with slight modifications, for lodgepole-pine cones. The shaker is composed of a parallelopiped 16 feet long and about 4 feet square at the ends, constructed on a shaft of 2-inch pipe long enough to provide for the supports at either end and for a crank with which to revolve it. Poultry net of $\frac{3}{4}$ -inch mesh for yellow-pine cones and hardwood cloth of $\frac{1}{2}$ -inch square mesh for lodgepole cones is stretched over the frame. The whole apparatus is made with a fall of about 6 inches, the end of the hopper being elevated that much to cause the cones to travel automatically through the shaker to the other end, where they fall out. The contrivance may either be operated by hand or by a gasoline engine. Cone shakers

¹ For more complete details, see Forest Service Circular 208, "Extracting and Cleaning Forest Tree Seed."

of this type may be made to "take down," so that they can readily be transported from place to place in the woods.

SEED CLEANING.

After the seed is separated from the cones there is still mixed with it a good deal of foreign matter, such as small twigs, pieces of cone scales, and membranous wings. Much of this foreign material can be screened out, but to loosen the wings from the seed requires further treatment. Removal of the wings may decrease the germinative power of seed to a small extent, but so greatly increases the ease with which they can be handled that the practice is almost universal.

WING REMOVING.

One of the oldest and commonest methods of removing wings is to work the seed over in seamless sacks, the mouths of which are securely tied. The wings are more readily removed from pine seed, to which this method is particularly applicable, if the seed are slightly moistened with cold water. This may be done by putting the seed in a box, adding a little cold water, and stirring. The entire wing may be readily detached from the seed of all the pines except longleaf; but the wings on the seed of other species form part of the seed coat and can be removed only by actually breaking them off, so that moistening the seed is of doubtful value. The sacks are beaten with light flails, usually of leather, or kneaded with the hands and knees. Sometimes the sacks are tramped under foot for a few moments, but this impairs the quality of the seed.

Another process is to pile the seed 6 or 8 inches deep on a cement or plank floor, sprinkle it lightly with water, and then beat it energetically with leather flails. The wings can often be removed completely with the use of very little water. The wings of pine seed may be removed by moistening them slightly and then churning the mass in a cylindrical drum.

Whenever a wet process is used the seed must be dried immediately, so that its vitality will not be impaired. The relative merit of dry and wet processes depends partly upon whether the seed is to be stored for some time or used within a few months. In the latter case a wet process is ordinarily safe. If the seeds are to be stored for a year or more, a dry process should be used.

Another method of removing wings is to churn the seed, together with a number of small wooden blocks, in a box or barrel mounted on an axle so as to be rotated; or the box may be kept stationary and friction applied by rotating brooms nailed to a spindle running through the center. In the latter case, if the box is tilted at a slight

angle and a hole cut in the lower end, the seed will gradually work out with the wings broken off.

Still other methods depend wholly on the use of screens. The simplest of these is to rub the seed as it comes from the extractor over a fine screen fastened on an empty box or stout frame. The rubbing may be done with a stiff scrubbing brush, a block of wood covered with corrugated rubber, a piece of tough carpet, or the hands covered with rough gloves. As the wings are rubbed off the seeds gradually drop through the screen, leaving a large part of the wings and all of the coarser impurities on top. One-sixth inch mesh is the best size for screening yellow pine and Douglas fir seed; for lodgepole pine and Engelmann spruce one-eighth inch mesh is preferable. The wings are more easily removed if the seed are moistened slightly with cold water before screening.

The first screening ordinarily does not remove the wings completely. To get rid of what is left, the seed and small chaff coming through the first screen may be churned, together with several small pieces of wood, in a small, cylindrical drum, covered with very fine-meshed wire. This removes the rest of the wings, which with other small particles of dirt, fall through the screening, leaving clean seed behind.

A somewhat similar method, preferable when the work is done on a large scale, makes use of a mechanical cleaner or wing crusher. This consists of a rotating cylinder bearing upon the outside several scrubbing brushes with stiff bristles, which, during about one-third of each revolution, press firmly against a wire screen of mesh fine enough so that the seed itself will not pass through it. The screen against which the brushes press as they revolve may be adjusted to regulate the pressure of the bristles against it. The seed is dropped into the space between the screen and the brushes, and the wings are removed as they pass under the brushes; the fragments of wings and chaff drop through the wire screen. When using such an apparatus with pine seed, a slight moistening of the seed with cold water is advisable before putting them into the hopper.

A device designed by Forest Ranger William Kerlee of the Bitterroot National Forest is both rapid and effective with western yellow pine. It consists of a rectangular churn 2 feet by 2 feet by 7 feet 8 inches. Longitudinally placed through its center there is a cylinder which is revolved in one direction by means of a belt. Upon this cylinder the churn itself is revolved in the opposite direction. From two opposite inner surfaces of the churn, wooden teeth project toward the cylinder, and on the cylinder similar wooden teeth project toward the periphery of the churn. The two sets of teeth overlap by several inches and clear each other by from one-fourth to one-half

inch. (See diagram of cross section, fig. 2.) The churn turns at the rate of 52 and the cylinder 168 revolutions per minute. One side of the churn is fitted with a hinged door to permit the reception of un-winged seed and their removal after churning. Three bushels of seed can be put through at a time, and about 80 bushels in a day. Each bushel will yield 10 or 11 pounds of clean seed, so that the daily capacity of the churn is from 800 to 900 pounds. This device has been found unsatisfactory in only one respect. Refuse mixed with the seed occasionally breaks out one of the teeth and this in turn is quite likely to break out several others. It is thought that this defect can be remedied by the use of teeth of spring steel.

SCREENING AND FANNING.

The final cleaning of seed is done by screening and fanning. Where no fanning mill is available, fairly clean seed may be obtained in the following manner: First, pass the seed through a wire screen to remove the coarser particles, such as pieces of cone scales, twigs, and

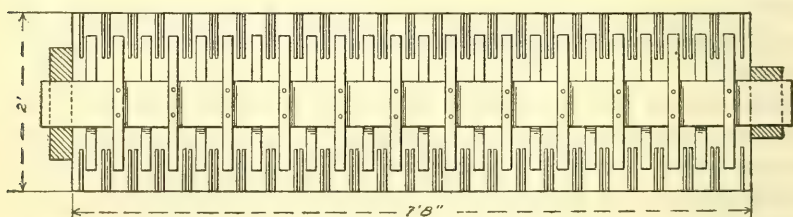
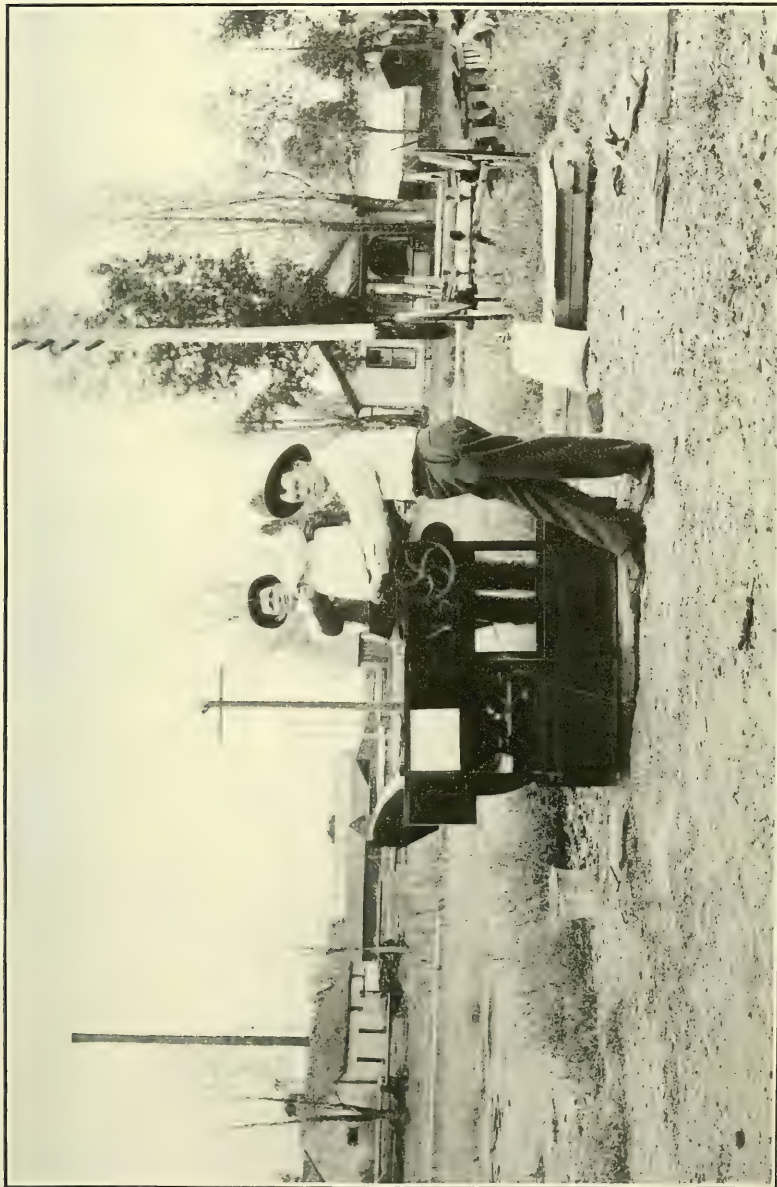


FIG. 2.—Cross section of wing-removing churn.

needles, and then through a screen of smaller mesh to remove the finer chaff and pieces of broken wings; second, winnow the remaining seed in the wind or by bellows or other mechanical devices.

Seed may be fanned in one of the ordinary farm machines for cleaning grain (Pl. V). They remove practically all broken and empty seed as well as much of the resin and other impurities, if the draft is properly regulated and the screens with the right-sized mesh are used. It is essential that the wings be removed from seed before fanning, otherwise many good winged seeds will be lost. Not infrequently, particularly with poorly adjusted machines, the seed must be fanned more than once before it is thoroughly cleaned.

By the use of a grain-grading machine, the extracting plant at the Trapper Creek Nursery divides the seed into four different classes. The grading is accomplished by means of a fan, so that the classification is by weight. Germination tests of western yellow pine carried on for 45 days gave a germination of 13½ per cent for seed of class 1, the heaviest seed; 1 per cent for seed of class 2, the next



RUNNING SEED THROUGH A FANNING MILL TO REMOVE DIRT AND CHAFF.

F-294319



heaviest; and one-half per cent for seed of class 3. Seed of class 4 was not tested; but this class is mostly débris and broken seed.

YIELD FROM CONES.

There is great variation in the yield of seed from a bushel of cones. The amount depends upon the quality of the cones, the thoroughness of the drying and extracting, and the manner of cleaning. The cones of any species fill better during a "seed year" than during "off years," so that in the former there is greater bulk, and especially greater weight of seed. Table 2 shows by species about the average quantity of seed per bushel of cones or fruits.

TABLE 2.—Quantity of seed per bushel of cones or fruit of different species.

[Quantity varies considerably in different regions or years.]

| Species. | Number of pounds. | Species. | Number of pounds. |
|---------------------------|-------------------|--------------------------------|-------------------|
| CONIFEROUS. | | CONIFEROUS—continued. | |
| Incense cedar | 2.50 | Engelmann spruce | 0.80 |
| Western red cedar | .75 | Sitka spruce | 1.25 |
| Douglas fir | 1.00 | | |
| Amabilis fir | 3.00 | HARDWOOD. | |
| Noble fir | 2.50 | | |
| White fir | 3.00 | Black walnut (husked) | 40.00 |
| Western hemlock | 1.00 | Butternut (husked) | 40.00 |
| Western larch | .50 | Chestnut (clean) | 50.00 |
| Lodgepole pine | .40 | Bitternut hickory | 40.00 |
| Norway pine | 1.00 | Pignut hickory | 40.00 |
| Sugar pine | 1.60 | Shagbark hickory | 30.00 |
| Western white pine | .75 | Red oak acorns (clean) | 50.00 |
| Western yellow pine | 1.50 | White oak acorns (clean) | 70.00 |
| White pine | 1.00 | | |

COST OF SEED.

Many factors influence the cost of seed, such as the quantity and quality of the crop, the species, the remoteness of the area from a railroad, the method and scale of collecting, the character of the weather during collection and extraction, and the method of extraction. Some costs per pound of seed gathered in fairly large quantities by the Forest Service are shown in Table 3:

TABLE 3.—Cost of seed.

| Species. | Cost per pound. | Species. | Cost per pound. |
|-------------------------|-----------------|---------------------------|-----------------|
| Incense cedar | \$0.70-\$2.25 | Jeffrey pine | \$0.42-\$0.84 |
| Western red cedar | 2.00 | Lodgepole pine | 1.70- 2.00 |
| Douglas fir | .66- 1.36 | Norway pine | 2.63- 3.19 |
| Amabilis fir | .36- 1.13 | Sugar pine | .50- .65 |
| Noble fir | .38- 1.13 | Western white pine | 2.43- 2.83 |
| Red fir | .53- .83 | Western yellow pine | .41- .67 |
| White fir | .23- .63 | Sequoia (redwood) | 1.63 |
| Western larch | 2.43 | Sequoia ("Bigtree") | .66- 1.22 |
| Jack pine | 3.41 | Engelmann spruce | 1.00- 2.41 |

NUMBER OF SEED PER POUND.

In Table 4 is given by species the approximate number of seed per pound.

TABLE 4.—*Number of seed per pound.*¹

| Species. | Number of seed. | Species. | Number of seed. |
|------------------------|---------------------|----------------------------|-----------------|
| Bigtree..... | 75,000 | Maritime pine..... | 9,450 |
| Increase cedar..... | 17,000 | Mexican white pine..... | 2,700 |
| Western red cedar..... | 400,000 | Norway pine..... | 54,000 |
| Arizona cypress..... | 100,000 | Scotch pine..... | 69,000 |
| Douglas fir..... | 43,000 | Sugar pine..... | 2,400 |
| Amabilis fir..... | 9,300 | Western white pine..... | 28,000 |
| Grand fir..... | 28,900 | Western yellow pine: | |
| Noble fir..... | ² 15,400 | Pacific Coast..... | 9,100 |
| Red fir..... | ² 67,000 | New Mexico..... | 16,000 |
| Austrian pine..... | 24,000 | Black Hills..... | 13,500 |
| Jack pine..... | 150,000 | White pine (New York)..... | 26,000 |
| Jeffrey pine..... | 3,100 | Engelmann spruce..... | 175,000 |
| Lodgepole pine..... | 120,000 | Sitka spruce..... | 400,000 |

¹ The number may often be more or less by from 5 to 20 per cent than the figures given.

² Not Forest Service tests.

SEED STORING.

Wherever possible clean seed should be stored in air-tight receptacles of glass or metal. Seed retains its vitality under any conditions of temperature and moisture much better in such receptacles than in any others, except when placed in cold storage, which is seldom available. Where neither of these methods of storage is available the seed should be thoroughly dried and stored in a dry and cool place. Some deterioration will take place under these conditions, but ordinarily not sufficient within one year to be of serious consequence. The storing of seed in cement cellars with the wings attached has been found by Austrian experimenters to give better results than storage with the wings removed. It is doubtful, however, whether the slight saving in vitality offsets the advantage of handling and using clean seed. In every case the seed should be thoroughly protected from rodents, by the use of poison, by being stored in rodent-proof buildings, or by being hung in sacks out of reach.

SOWING AND PLANTING.

STATUS OF THE WORK ON THE NATIONAL FORESTS.

DIRECT SEEDING.

Of the two methods of artificial reforestation, direct seeding and the planting of seedlings, the former where it can be practiced successfully offers the easiest and cheapest solution of the reforestation problem. The seeding itself is a much simpler operation than planting, and with inexperienced labor, which is all that is generally obtainable, it can be carried on in conformity with the most approved

practice better than planting. A far greater proportion of the Forest Service reforestation operations has been conducted by direct seeding than by planting. Of a total area of 124,732 acres covered up to June 30, 1915, 84,320 acres were seeded directly and 40,412 acres were planted. Practically all of the most important western species of trees and a number of exotics have been given a trial, a wide range of conditions has been covered, and a great variety of methods tested.

In many localities direct seeding has not been successful. In some instances when success or partial success was at first reported it has developed later that, although good germination was secured, the seedlings were killed by drought, birds, frost, or severe winters. Efforts in direct seeding have strongly emphasized the fact that the success of plantations so started can not be judged until they have passed through a period of at least three years. The results obtained already indicate that if rodents are controlled and two or three favorable years in succession follow sowing, direct seeding can be made to succeed on the more favorable sites. No final conclusion, however, has yet been reached regarding the merit of the direct seeding method, and investigations are now being carried on in a more intensive manner on smaller experimental areas.

Consistent success in direct seeding has been obtained with lodgepole pine on the Arapaho National Forest in Colorado. Here, on northerly slopes at altitudes between 8,000 and 10,500 feet, broadcasting on the snow and seed spotting, both being done in the fall, have quite regularly given good results. Broadcasting has been conducted only on areas where the soil was exposed—that is, not covered with duff or a heavy growth of grass—while seed spotting is employed even where such ground cover exists.

Direct sowing of maritime pine on the Florida National Forest appears promising when the seed is broadcasted on plowed ground and covered by means of a brush drag. Plantations started in this manner have passed successfully through a three-year period. Sowing on plowed strips three furrows wide and on harrowed strips, the seed being covered in each case with a brush drag, also gives promise of success. Seed spotting is the least successful method tried, except broadcasting without preparation. All of these operations must be carried on in October after fall rains have started; and rodents must be eradicated or greatly reduced to obtain success.

PLANTING.

On the greater portion of the National Forest areas in need of forestation it is probable that planting is ultimately more successful and cheaper than direct seeding. Results in plantations which have

not yet passed through the three-year trial period tend to show that success may be expected on from 75 to 100 per cent of the areas covered, provided the operations are conducted during the right season and suitable stock is used. To determine these points, as in direct seeding, intensive experimental work is being conducted on the National Forests in addition to extensive forestation operations.

As the Forest Service nurseries have developed and planting stock has been produced more abundantly, planting operations have gradually increased in scope. During the fiscal year ending June 30, 1914, 9,400,000 seedlings or transplants grown in Forest Service nurseries were planted, the operations covering 14,063 acres in western United States and being carried on under a wide range of conditions.

SOWING AND PLANTING METHODS.

The methods followed in forest sowing and planting should be governed, first, by the success, and, second, by the economy which attends them. When the Forest Service began this work in the West, there was no experience to indicate how operations could be successfully conducted. Numerous methods have been tried, with varying degrees of success; but it can not yet be said that those best adapted to the several regions and many different soil and climatic conditions in the West have been entirely worked out. A good start has been made, however, and a number of these methods will, accordingly, be discussed.

SOWING.

BROADCASTING.

In broadcasting, seed are scattered by hand or by the use of a mechanical sower in much the same manner as grain. The best practice is to go over the whole area and sow half the seed; then to traverse it again at right angles to the previous courses and sow the other half. This insures a more even distribution of the seed. Large or medium-sized seed, such as sugar pine or western yellow pine, can be sown by hand; but small seed, such as lodgepole pine, larch, and spruce, can be handled better with a mechanical seed sower. When very small seed are used, they can be scattered more uniformly by mixing them with fine, dry earth.

In general the rugged topography of the country, the inaccessibility of the planting sites, or the presence of dead and down timber makes preparation of the ground by such methods as plowing or harrowing impossible. In only a comparatively few cases has it been done. In deciding upon the best method of preparing the ground for sowing, the surface, slope, and character of the ground cover, as well as the species to be sown, must be considered. Some of the



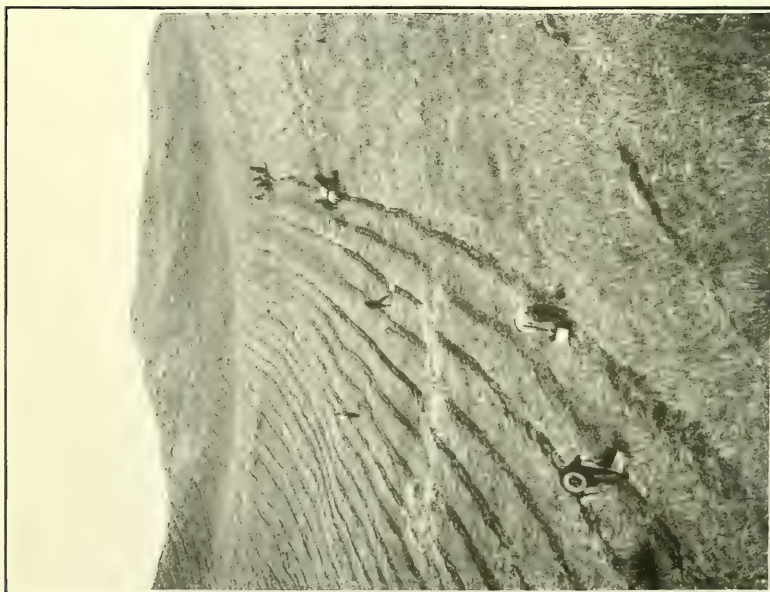
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FIG. 1.—BROADCAST SOWING OF DOUGLAS FIR SEED ON SNOW. SIUSLAU NATIONAL FOREST, OREG.



F-84099

FIG. 2.—PLANTING WESTERN YELLOW PINE SEED ON LOLO NATIONAL FOREST, MONT., BY MEANS OF CORN PLANTERS.



F-2725A

FIG. 1.—PLANTING ON NEBRASKA NATIONAL FOREST, WITH
PLOW AND FIELD TRENCHER.



F-2734A

FIG. 2.—PLANTING ON OREGON NATIONAL FOREST, NEAR
MOUNT HOOD.

methods which have been used are burning, harrowing with an ordinary spring-tooth or disk harrow, dragging tree tops or stumps over the ground, and plowing. An area thoroughly trampled by sheep or which has been used as a sheep driveway, the soil of which has become loose, is usually in good condition for sowing. Covering broadcasted seed by harrowing or otherwise is not usually practiced. Where it has been tried, better germination has sometimes been secured on experimental areas, but the final stand has been little, if any, better. On a successful broadcasted area of Douglas fir on the San Isabel National Forest the seed were raked in by hand.

The best results with broadcast sowing may be expected where the soil is loose and moist at the surface, where some protection is afforded seedlings against heat and drought, and where rodents can be controlled. Burned areas covered with down timber, aspen, or brush of not too dense a character, and without much leaf litter, offer good sites for broadcast sowing without preparing the ground or covering the seed.

Broadcasting has in general proved the least successful of direct seeding methods. It requires large quantities of seed; it is expensive, particularly so where some method of preparing the ground or covering the seed is followed; the seedlings are likely to come up in groups because of the erosion of the soil and destruction of the seed by rodents; and it must be largely confined to sites where the mineral soil is exposed, usually burned or logged over areas. On the other hand it is a simple and rapid method, one man being able to cover from 20 to 40 acres in a day; and operations can be conducted during winter, the season when other work is not pressing. (Pl. VI, fig. 1.)

SOWING IN STRIPS AND BLOCKS.

Strip sowing and block sowing are modifications of the broadcast method. Sowing in strips has the advantage that it does not require the covering of the entire area. Narrow strips, 3 feet wide or less, are sometimes prepared in various ways, such as plowing, harrowing, or raking. Sometimes no preparation at all is given. On hillsides the prepared strips should run along contour lines, not up and down. Strips so run catch and retain the precipitation, and also prevent the soil and seed from being washed down by rain. In a flat country they should run east and west, and when a plow is used, the furrows should be turned toward the south. This will give the seedlings some protection from the sun during the first year. Less seed per acre is required in strip sowing, but the seed is sown more thickly per square rod on the strip seeded than on the area broadcasted. Strip sowing is a method particularly adapted to quick-growing species which will soon bear seed and thus seed up the intervening areas.

REGULAR SEED SPOTS.

In the seed-spot method small spots quite regularly spaced over the area are more or less prepared for the reception of the seed by loosening the soil with some tool. After the seed are sown on each spot they are usually covered with soil to a depth of about one-half inch and often with an additional mulch of needles or leaves. On the Arapaho National Forest, where the most consistent success with direct seeding of lodgepole pine has been achieved, the seed when sown in this way are simply pressed into the soil and not covered. Meager success in direct seeding by seed spotting is probably due in many cases to the planter covering the seed too deeply. When the seed is not covered at all this danger is obviated.

The size of the spot and the depth to which the soil is loosened depend upon the character of the ground cover and the species to be sown. The spots are usually from 10 to 20 inches square. Where the ground cover consists of strong growing plants, such as grasses, which will compete with the seedlings for moisture, wide spots are prepared and a portion of the competing vegetation thus destroyed. Where a shade-enduring species is sown on a moist situation, the competition does not become so critical and the smaller spots are satisfactory. In locating them, advantage is taken of any shelter on the ground, such as brush, logs, or rocks, which will serve to shade the soil and seedlings during a portion of the day. For the same reason, on level ground the turf is thrown upon the southern side of the spot. On slopes the soil is thrown upon the lower edge of the spot. This aids in holding moisture and precludes washing of the soil from above, with the consequent burying of the seed too deeply or the covering of the seedlings. As too deep covering of the seed through the filling in of soil from above is doubtless often the cause of loss, it is better on slopes to prepare seed spots simply by loosening the soil, but not making any depression at all in the slope. The chief functions of the spot are to make sure that the seed reaches the mineral soil and partially to eliminate for a time competition of grass and other plants.

SIMPLE SEED SPOTS.

The simple seed-spot method differs from the regular seed-spot method principally in that the spot is smaller and somewhat deeper. It is usually prepared with one stroke of the mattock. Its chief claim to merit was that on account of its depth it was thought that the earth surrounding the hole would both shade the seedlings and protect them from winds. It would accordingly be especially suited for seeding on very dry, barren, stony ground or in hot or windy situations. A serious objection to this type of seed spot is that soil

is likely to wash or crumble in from above and cover the seed so deeply that the germinating seedlings can not push through. Leaves and other litter are also likely to collect in these spots and smother any seedlings which may get a start.

CORN PLANTER SEED SPOTS.

In the corn-planter method seed are distributed at fairly regular intervals by means of corn planters which are regulated to drop the desired number of seed in each spot. More ground can be covered per man by this method than by any other, except broadcasting. In experimental work on the Uinta National Forest from 5,000 to 6,000 spots per man per day have been covered, but from 2,000 to 3,000 is a more common rate. This method has in a number of instances proved fairly satisfactory; but none of the corn planters covers the seed well, and as it is bunched in a mass, it is easily located and destroyed by rodents.

CHOICE OF METHODS.

The results from the use of all of these methods have been so uncertain that none can be positively recommended, nor has any one proved distinctly superior to the others. Over a broad range of conditions, however, it is thought that the "regular seed spot" method offers the best possibilities because a good seed bed is prepared, the seed comes in contact with mineral soil and can be covered properly; only a small amount of seed is required per acre, and the resulting stand is quite likely to be evenly distributed. This method can be used over a greater variety of sites than any other with better chances of success.

PLANTING.

SLIT METHOD.

The slit method consists simply of opening a wedge-shaped crevice in the ground by driving a spade, mattock, or axe into the soil and moving the handle backward and forward or sidewise a little (fig. 3). A hole 2 or 3 inches broad at the top, as wide as the blade of the tool, and tapering to an edge at the bottom is thus formed. Into this crevice the roots of a plant are thrust and shaken down as well as possible. The soil on each side of the hole is then compacted against the roots by means of vigorous tramping and stamping with the foot or by inserting the tool into the soil again on the far side of the plant and prying the soil toward it. Before making the slit the surface soil and sod is scraped away sufficiently to remove debris or dry soil which may fall into the hole when the tool is removed. Further, when the mattock is used, the soil over an area 6 or 8 inches

square is ordinarily loosened to the depth of the mattock blade and the cleft is then made in the center of the loosened area.

The principal advantage of this method is that it is rapid, and, where it can be practiced successfully, correspondingly economical. Moreover, it makes possible the covering of large areas during a planting season. On the other hand, it can not be followed to good advantage except in soil which is fairly loose and free from rocks, because it is difficult to make a deep enough cleft in heavy or rocky soil; and, what is still more important, a cleft in such soil can not be properly closed by tramping after the seedling is inserted. Where the cleft is not properly closed air spaces are left around the roots, causing them to dry out; and the death of the plant follows. Further, careless or rapid planters often will not take the trouble to see that the roots are not bent, and that the root tips are not near the surface

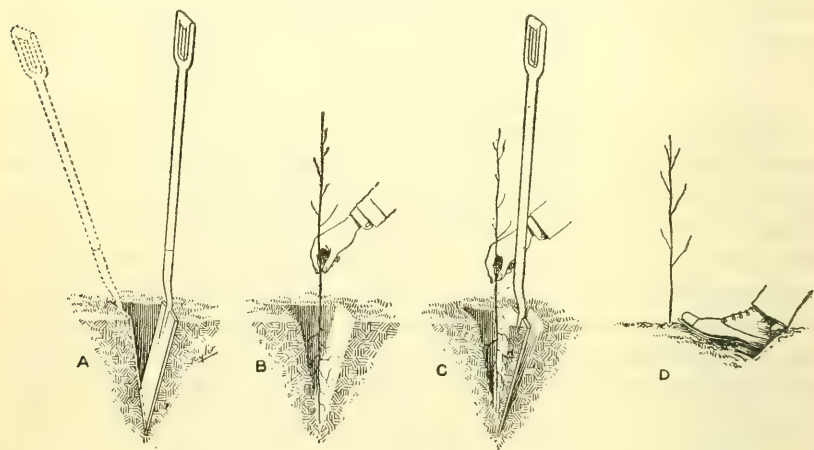


FIG. 3.—Slit method. A, Open slit with spade; B, insert tree and hold with hand until set; C, close slit by thrust of spade; D, close entire hole by thrust of heel.

of the soil where they will soon dry out. Such planting is almost certain to result in failure. The method has been followed successfully, however, particularly on the Nebraska National Forest in the sandhill region, where a crew of two men will average about 2,000 plants per day of eight hours.

A modification of this method is sometimes called the "grub-hoe method." In this the grub hoe or mattock is driven into the soil to the depth of the blade; the tool is pulled slightly toward the operator; the roots of a plant are thrust into the opening thus formed back of the tool; and the blade is then lifted in such manner that the loosened soil slides off upon the roots of the plant. This soil is then well tramped about the roots. The method is simple, easy to perform, and rapid; and the soil is not scattered. Planting can be carried on at an average of from 600 to 800 trees per man

per day, and as many as 1,000 under favorable conditions. On good soils and in regions very favorable to tree growth, as in Washington, Oregon, and western Idaho and Montana, this method has proved very successful. It is not yet known, however, that it will be successful in regions or on sites not particularly favorable to tree growth. The hole opened up is not large enough or deep enough to allow the proper distribution of the roots; it usually does not remove much of the competing herbaceous growth; and it does not permit especial attention being given to the packing of the soil around the roots.

TRENCHER METHOD.

The trencher method is simply a modification of the slit method. One of its best features is breaking up heavy sod or herbaceous growth and thus freeing the seedlings from root competition and excessive shading. The field trencher and its use have been described as follows:¹

The trencher consists of a heavy V-shaped shoe fastened on an ordinary steel plow beam and supplied with handles similar to plow handles. The shoe is 24 inches long, 12 inches deep, and is made V-shaped by riveting plates of steel together at the bottom and separating them 3 inches at the top. These plates are welded and drawn out into a thin sloping edge in front, the lower part of which is widened into a broad nose. The nose draws the shoe into the soil, and a small horizontal plate attached to the bottom of the shoe serves to hold it to an even depth.

With a strong slope from the nose to the top of the shoe in front, roots and trash in the soil that are not severed when the shoe strikes them are inclined to be raised above it and then slide off at one side of the beam without injuring the trench. The length of the shoe is such as to cause the sides of the trench to be sufficiently troweled to make them stand up until the planter comes along to put in the tree. The use of a short shoe results in the trench caving down and half filling in many places almost immediately after the trencher has passed.

The trencher is drawn by three horses, and in its use on the Kansas and Nebraska National Forests the trench is usually made in a furrow turned with a sidehill or ordinary plow. A man with a planting basket follows the trencher and puts trees into the trench, being careful to have the roots well extended toward the bottom. As the crowns of the trees are brought to the proper height, the planter sets his foot at a slight angle to the trench, caving the side in against the roots. Men with long-handled tampers follow, setting the soil firmly against the trees, and close the trench between the trees to reduce the chance of evaporation. A gang of 10 to 15 men is required to keep up with the trencher and can plant from 12,000 to 20,000 trees per day.

On the Kansas National Forest this scheme was brought nearer to perfection by the use of a riding trencher, which combines a lister plow with a trencher and thus saves the expense of one driver and two horses.

¹ Mast, William H. *In American Forestry*, Vol. XVIII, No. 5.

Up to the present this method has been followed only on the Kansas and Nebraska National Forests; it has proved rapid on both and successful on the Nebraska (Pl. VII, fig. 1). The method, however, is limited in its scope. It can not be followed on very steep hillsides, in soil that is rocky or filled with large roots, or on areas covered with brush or considerable down timber; and it is questionable if it would be successful in very heavy soil. In short, the method is not suitable for the greater proportion of the lands in the West on which forest planting will have to be conducted.

SQUARE OR DEEP-HOLE METHOD.

A square hole seven or eight inches across and about a foot deep is dug, either with a spade or a mattock; and for utility in planting, the soil removed is placed adjacent the hole (fig. 4). Properly,

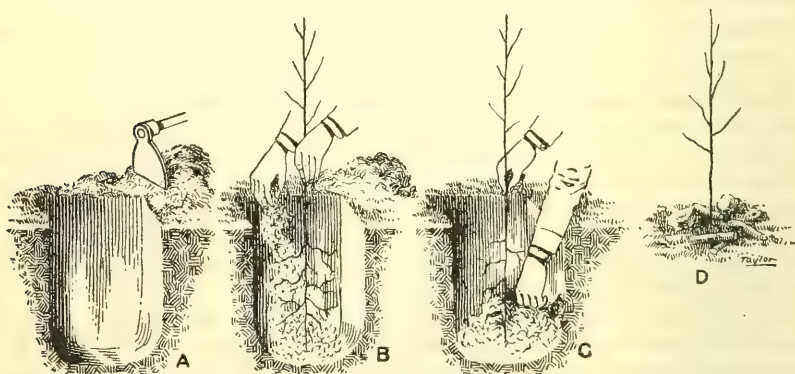


FIG. 4.—Deep-hole method. A, Digging hole; B, partially cover roots with loose moist dirt; C, tamp dirt firmly about roots before filling hole full; D, place objects about tree to prevent erosion and trampling.

the soil removed should be kept in two separate piles; the moister, richer soil of the upper layer in one pile, and the lower subsoil in the other. The depth of the holes depends upon the size of the stock; they should be deep enough so that the roots may hang straight down in their natural position when the tree is set at the same depth as in the nursery. The tree is held by the root stock with the fingers between the different ramifications of the roots so as to spread them apart. This is done with the left hand, while the dirt is filled in with the right. The moist, better soil is first drawn in over the roots and packed well around them with the fist; then the remainder of the soil is thrown in and part of it well packed, a portion lying on top being left loose to serve as a mulch. On slopes, the aim should be to leave the surface of the soil at the same angle as the slope of the planting site instead of leaving a depression in the soil. Where a depression is left, soil from above is apt to wash into it, or leaves may

drift in and partly or entirely cover the plant. The drifting in of leaves has caused considerable loss where the planting has been done under a stand of aspen.

This method is the most applicable to all species and sites; it removes part of the competing growth of sod; and it (or a modification of it called "side-hole method") will undoubtedly continue to be the one in most general use in the future. It is only fairly rapid, from 250 to 350 trees per man per day in rough country constituting an average day's planting, and there is the possibility of poor planting if the crew is not careful to spread the roots during the operation.

In the side-hole method the trees are set against one side of the hole instead of in the middle. It is a little more rapid than when the trees are set in the middle of the hole; and, experimentally, in operations on the Siuslaw National Forest and at the Fort Valley Experiment Station, it has proved almost as successful. It can not be given unqualified indorsement, however, without further trial, though with the ordinary planting crew it will probably prove just as successful in the majority of operations as planting in the center of the hole.

CONE METHOD.

The cone method is another modification of the square-hole method. The square hole is dug as in the other method; a mound of earth is then built up by the planter in the bottom of the hole, and the roots of the plant are spread over this mound. Thus they come in contact with a greater amount of soil, from which moisture and other plant nourishment can be drawn. After spreading the roots, the soil is filled in as in the square-hole method.

This method unquestionably has merit for planting under very unfavorable conditions; for, if it is properly conducted, the losses are usually smaller than where other methods are used. On the other hand, it has disadvantages. It is not applicable to species which do not have a ramifying root system; unless given close supervision, the average workman will not be particular to form a good cone or to spread the roots well over it; and it is slow and expensive. Under average conditions one man will plant only from 200 to 250 trees per day.

PLOWING AND MATTOCK METHOD.

Single furrows are plowed from 8 to 10 feet apart, and holes are then dug with a mattock to receive the plants. It has been found that just about twice as rapid progress can be made as where no plowing is done, both in digging holes and in planting, because digging is easier in the broken sod and more loose dirt is provided for filling in around the trees.

Like any other method where a plow is used, this is subject to limitations; but on account of its rapidity and the success which has attended its use, it is worthy of trial, particularly in grassy or sagebrush land where the plow can be used. On steep, grassy sidehill areas open to grazing by cattle there is a serious drawback to this plan; the animals follow the furrows as paths and are likely to tramp out a large proportion of the planted stock.

PIT METHOD.

The pit method is designed particularly for use in regions which, following the planting season, become particularly hot and dry. It has been used by the Forest Service mostly in fall planting in southern California. It consists in partially preparing the holes in advance of the planting operations. Spots are cleared about 16 inches square and the surface soil stirred to a depth of about 8 inches. Then in a spot about 8 inches square in the center the soil is removed to a depth of from 12 to 16 inches in order to loosen it up thoroughly. It is then replaced and a depression left on top. Where the original method is adhered to, the work is finished a month or more before the time of planting.

Rain which will saturate the hard ground only to a depth of 2 or 3 inches will be sufficient to penetrate from 12 to 16 inches in the soft soil of the pits. This is one of the most important points in their favor. Soil when moist to a depth of 12 inches is suitable for planting. Thus, when the contiguous land is not ready for planting and may not be for some time, the soil in the pits is moist enough to make planting feasible, so that operations may be finished before the advent of cold weather. The plants will then have a better opportunity to become partially established during the fall.

The other most valuable feature of pits is that their soil, before it becomes packed by rain or snow, will remain moist two or three weeks longer than the untilled adjacent soil. Accordingly, trees in pits should not, under dry conditions, suffer from lack of moisture as soon as those planted on untilled land. Another advantage is that the soft earth can be very easily removed when the planting operation is in progress, enabling more rapid work and the covering of a greater area during the most favorable planting season, which is often of short duration.

Advance preparation of pits in some particulars has decided disadvantages. Crews have to be assembled to prepare the spots, and again later on for planting; the holes have to be dug twice, which makes the operation expensive; and when the planting is in progress some of the spots previously prepared may be missed. In Forest Service operations this method has been discontinued; be-

cause although theoretically it seemed destined to assure better results, practically it has not done so. Fully as good results have been achieved by preparing the holes at the time of planting as by preparing them a month before.

POT PLANTING.

Sometimes stock which has been grown in paper pots is planted. The whole pot is planted either in a hole or a pit. The pot is set in the hole and the loose soil thrown in and firmed closely around it and piled up enough to cover its top.

Pot planting is particularly designed for arid and semiarid regions or for summer planting. The roots are not disturbed or exposed during the operation, and good soil is retained around them. This is decidedly conducive to success, particularly in dry regions. It permits of summer field planting, because the plant, which is growing, is not disturbed to any appreciable extent during the process.

When tried in Arizona the method was not especially successful. Better results at a much lower cost were secured through planting vigorous, sturdy bare-rooted stock. In southern California developments up to date indicate that the method may prove the most suitable in reforestation operations in that region. The greatest success through its use has been secured largely in experimental work with incense cedar and western yellow and Jeffrey pine.

Some objections to the method have developed. The planting stock itself is unduly expensive because of the cost of the pots and the individual attention which must be given to each plant in producing it. Moreover, it is difficult and expensive to transport and distribute the pots over the planting site. The pots form a ready line of cleavage with the soil and have in some instances been heaved up with the plant out of the ground during periods of alternate freezing and thawing weather. Further, the best root development is not secured, and after the pots are set out in the field there is a decided tendency for the roots to remain confined to the good soil of the pots rather than to reach out into the surrounding soil.

BALL METHOD.

The ball method consists in removing each tree from the nursery with a ball of the nursery soil surrounding the roots and planting it in the field in this condition. Almost the same advantages would result from this as from pot planting, but it is obviously impracticable thus to remove the small trees used in forest planting.

CARE IN PLANTING.

In planting operations there are a number of points to be kept in mind. Special attention must be called to the susceptibility of coni-

fers to mortal injury through the drying out of their roots. A short period of exposure may bring this about, such as when they are dug from the transplant beds, while they are being counted or heeled in, while en route to the planting site, or during the operation of planting. Drying out may occur at any one of these times; and yet if the roots are afterwards moistened there will be no evidence of the injury, because coniferous tops will remain fresh, green, and bright for some time after the death of the roots, and will reach the hands of a planter apparently in a perfectly vigorous condition. When field planted, however, they will lose their color and shed their leaves in a month or so.

When the crated trees arrive at their destination on the railroad they should be removed at once to the planting site. Wagon transportation is the most effectual over roads and pack animals over trails. When it is necessary to use pack animals the practice of unpacking the trees from the crates and repacking them in the ordinary alforjas or panniers carried on pack saddles should not be followed. This involves an extra handling of the stock, which means both expense and possible harm from exposure. It is a practice which should be discouraged. It can easily be obviated by packing trees at the nursery in boxes of a size which can be readily carried by a pack horse; that is, boxes which, when filled with trees, will not weigh more than 75 or 100 pounds each. While en route the crates should be covered to protect them from the sun and wind.

On arrival at the planting site, the trees should be heeled in (Pl. VIII, fig. 2). This is a simple but effective means of keeping the roots moist. In a cool, moist, shady situation a trench is dug about the depth of the spade, from 10 to 12 inches, with one of its sides slanting at an angle of about 45 degrees. Against this side a layer of trees is placed with their tops projecting above the surface of the ground and their roots extending down this slanting side to the bottom of the trench. From 4 to 6 inches of moist earth should then be thrown against the roots, worked in around the stems, and then firmed by foot pressure. If needed, another trench can be dug in front of this and the process repeated. If it is necessary for the stock to remain heeled in for a considerable period, the soil about the roots should be kept moist by watering. Ordinarily, the trees can be heeled in in bundles as they come from the nursery, but it is preferable at all times to spread them out in a thin layer not over 1 or 2 inches in thickness. As they are needed they can be dug up and used in the planting operations. When plants are to be heeled in during the fall to await spring planting, experience has shown that they should never be heeled in in bundles, but should by all means be spread out in a thin layer. Moreover, where the snow accumulates to a considerable depth, stock heeled in over winter should be so

placed that the tops of no two successive layers overlap. Wholesale losses from heating and molding, induced apparently by pressure of the snow, have occurred where the tops have overlapped. Fall heeling in for spring planting has in a number of instances proved very unsatisfactory, and it is a practice which should not be followed if avoidable. At no time, in fact, should plants be heeled in for a long period because loss of vitality results.

For spring planting on the Gunnison National Forest, crates of Douglas fir trees received from the nursery before planting could be

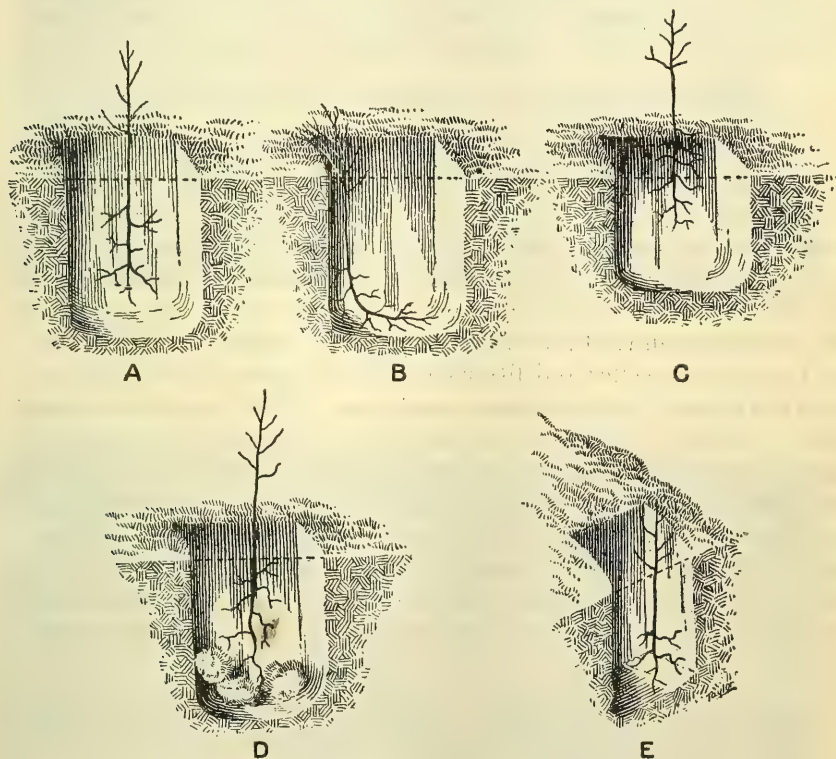


FIG. 5.—Reforestation on the National Forest. A, Good planting (tree will live if firmly set); B, careless planting (tree set too deep and roots crowded; will very likely die); C, very careless planting (tree set too shallow; will surely die); D, careless planting (sod, grass, etc., tamped around roots; will dry out and tree will die); E, careless planting (tree set too deep on side hill; will be covered by soil rolling from above).

conducted were buried in snow. This stock kept in excellent condition until it could be planted.

Too often, without a doubt, failures in planting are ascribed to improper methods of planting, inhospitable sites, etc., when in reality they are due to exposure of the roots at some time during the period following digging at the nursery. Every care must be taken, therefore, to guard against this. Care must also be taken against heeling

in the trees in hot, exposed situations and against their heating in the bundles, crates, or while heeled in.

Pains should be taken during the actual planting to observe the following: The planting holes should be deep enough (10 to 12 inches) and broad enough (8 inches or more) to accommodate fully the roots of the planting stock; the planting should be neither too deep nor too shallow; the soil packed around the roots should be moist and well firmed; the more fertile upper layers of soil should be packed around the roots, but sod should be excluded because it leaves air spaces and causes the drying out of the roots and the death of the plant; and depressions should not be left around trees planted under aspen or deciduous brush or on steep slopes (fig. 5).

QUANTITY OF SEED AND NUMBER OF PLANTS PER ACRE.

In the forest nature produces seed abundantly, depending upon quantity to offset possible adverse conditions. In artificial sowing it is not practicable to be so lavish; and conditions that will permit the germination of the seed and enable the plants to grow must, so far as possible, be insured. One of the chief problems is to get the seed into direct contact with the soil. An old grove of Douglas fir trees may shed 25 pounds of seed to the acre, or 1,250,000 individual seed; yet, because of needles and litter covering the ground, very few seed reach the mineral soil, germinate, and grow. With Douglas fir direct light is, of course, an important factor also. By removing the heavy shade, burning the litter, and exposing the mineral soil, and by poisoning destructive rodents, conditions may be so improved that 3 pounds of seed to the acre, sown broadcast, or 1 pound sown in seed spots, will produce a full stand of young trees. Areas sown by the seed-spot method suffer more damage from birds than do those sown by other methods. A thicker sowing in the spots is therefore necessary.

TABLE 5.—*Approximate percentage of germination of fresh seeds of different species under greenhouse conditions.*¹

| Species. | Germination. | Species. | Germination. |
|--|------------------|--|------------------|
| | <i>Per cent.</i> | | <i>Per cent.</i> |
| Bigtree (Sequoia washingtonia)..... | 33 | Norway pine (Pinus resinosa)..... | 89 |
| Arizona cypress (Cupressus arizonica)... | 22 | Scotch pine (Pinus sylvestris)..... | 44 |
| Amabilis fir (Abies amabilis)..... | 22 | Sugar pine (Pinus lambertiana)..... | 51 |
| Douglas fir (Pseudotsuga taxifolia)..... | 55 | Western white pine (Pinus monticola)... | 57 |
| Grand fir (Abies grandis)..... | 34 | Western yellow pine (Pinus ponderosa)... | 75 |
| Noble fir (Abies nobilis)..... | 23 | White pine (Pinus strobus)..... | 55 |
| Red fir (Abies magnifica)..... | 65 | Western red cedar (Thuja plicata)..... | 67 |
| Austrian pine (Pinus austriaca)..... | 67 | Engelman spruce (Picea engelmanni)... | 60 |
| Jeffrey pine (Pinus jeffreyi)..... | 86 | Norway spruce (Picea excelsa)..... | 48 |
| Lodgepole pine (Pinus murrayana)..... | 83 | Sitka spruce (Picea sitchensis)..... | 51 |
| Mexican white pine (Pinus strobiliformis)... | 47 | | |

¹ Individual lots of seeds vary greatly in their germinative ability. Under field conditions, germination is usually less than in the greenhouse.

² Tests not made by the Forest Service.



F-84094

FIG. 1.—PLANTING WESTERN YELLOW PINE ON BURNED-OVER AREA. LOLO NATIONAL FOREST, MONT.



F-14220A

FIG. 2.—WIRE-PACKING CRATES AND METHOD OF HEELING-IN PLANTS AT PLANTING SITE.



With a suitable area well prepared, the amount of seed of the more important species required per acre is about that shown in Table 6. The amounts are based on the average germination per cent given in Table 5. These quantities should be varied, as germination tests differ from those shown in this table or as spacings of seed spots differ.

TABLE 6.—*Number of seed required per acre.*

BROADCAST SOWING OVER THE WHOLE AREA.

| Species. | Seed per
acre. | Species. | Seed per
acre. |
|------------------------|-------------------|--------------------------|-------------------|
| | <i>Pounds.</i> | | <i>Pounds.</i> |
| Western red cedar..... | 1½-2½ | Mexican white pine..... | 8-10 |
| Douglas fir..... | 4-5 | Norway pine..... | 4 |
| Amabilis fir..... | 8-10 | Scotch pine..... | 7-8 |
| Grand fir..... | 8-10 | Sugar pine..... | 10-20 |
| Noble fir..... | 8-10 | Western white pine..... | 8-10 |
| Red fir..... | 8-10 | Western yellow pine..... | 6-8 |
| Austrian pine..... | 8-10 | White pine..... | 8-10 |
| Jeffrey pine..... | 18-24 | Engelmann spruce..... | 2-4 |
| Lodgepole pine..... | 2-3 | Norway spruce..... | 5-7 |
| Maritime pine..... | 10-20 | Sitka spruce..... | 2-3 |

SEED-SPOT SOWING.

[Spots spaced 7 by 8 feet; approximately 10 to 12 good¹ seed per spot.]

| | | | |
|------------------------|----|--------------------------|----|
| Bigtree..... | 1 | Maritime pine..... | 2 |
| Western red cedar..... | ¾ | Mexican white pine..... | 1½ |
| Arizona cypress..... | 1½ | Norway pine..... | ¾ |
| Douglas fir..... | ¾ | Scotch pine..... | 1½ |
| Amabilis fir..... | 1½ | Sugar pine..... | 3 |
| Grand fir..... | 1½ | Western white pine..... | 1½ |
| Noble fir..... | 1½ | Western yellow pine..... | 1½ |
| Red fir..... | 1½ | White pine..... | 1½ |
| Austrian pine..... | 1½ | Engelmann spruce..... | ¾ |
| Jeffrey pine..... | 4 | Norway spruce..... | 1 |
| Lodgepole pine..... | ¾ | Sitka spruce..... | ¾ |

¹ For example, if the germination tests showed 50 per cent germination, 24 seed would have to be sown to have 12 good seed.

A standard stocking of about 800 trees per acre has been adopted for nearly all of the planting operations on National Forests. This stocking is undoubtedly not the most desirable for all species or sites, but is considered the best to adopt as a general standard. As more becomes known about the various species, different spacings will doubtless prove more suitable. Uniform stocking has the advantage of facilitating calculations and making comparisons of different planting operations. As a matter of fact, because of the roughness of the country, the rocks, logs, and brush on the planting areas, uniformity in stocking is not attained. The number of trees planted per acre varies from 600 to 1,000 or more.

COSTS.

The elements which have a material bearing upon the cost of sowing or planting are many, and are sometimes unforeseen. The

topographical features, soil, and cover of the area, the distance of the site from the railroad and base of supplies, the character of the transportation necessary to convey the stock and supplies to the camp, the wages paid crews, the efficiency of the crews, the method followed in sowing or planting, the species and amount of seed or stock used per acre and its cost, the size of the operation, and the nature of the weather during operations all are important. Small operations are consistently more expensive per acre than large ones because the former do not continue long enough for the men to become expert in their work. Inclement weather which causes an interruption in operations often materially increases costs, because the men while idle are furnished food. The variation in these factors is so great that it is difficult to do more than estimate approximately the cost of any individual operation. That some idea may be obtained, however, the actual cost of a number of representative Forest-Service operations are shown in Tables 7 and 8.

TABLE 7.—*Cost per acre and per 1,000 spots of sowing different species in different regions by various methods.*

| Region. | Species. | Method. | Cost per acre. | Cost per 1,000 spots. |
|------------------------------|---------------------------------------|------------------------------------|----------------|-----------------------|
| Northern Idaho..... | Western white pine..... | Corn planter..... | \$2.16 | \$3.18 |
| Southern Montana..... | Lodgepole pine..... | do..... | 11.07 | 9.15 |
| Do..... | do..... | do..... | 12.49 | 4.59 |
| Southwestern Montana..... | do..... | Broadcast and harrowed..... | 20.78 | ..... |
| Do..... | do..... | Broadcast on snow..... | 9.87 | ..... |
| Do..... | Western yellow pine..... | Broadcast..... | 14.30 | ..... |
| Do..... | do..... | Corn planter..... | 1.59 | 1.75 |
| Do..... | do..... | Seed spot in plowed strips..... | 20.15 | 16.65 |
| Do..... | do..... | Mattock seed spots..... | 19.37 | 7.12 |
| Do..... | do..... | Corn planter on plowed strips..... | 7.21 | 10.60 |
| Western Idaho..... | Black walnut..... | Seed spot with pointed stick..... | 9.10 | 7.52 |
| Do..... | Western white pine..... | Corn planter..... | 3.18 | 2.63 |
| Central Montana..... | Western yellow pine..... | Broadcast..... | 4.68 | ..... |
| Western Montana..... | Western white pine..... | do..... | 4.83 | ..... |
| Do..... | do..... | Corn planter..... | 2.92 | 2.83 |
| Do..... | do..... | Hoe seed spots..... | 4.67 | 4.53 |
| Central Colorado..... | Western yellow pine..... | Broadcast on snow..... | 3.06 | ..... |
| Southwestern Colorado..... | Douglas fir..... | Plowed strips and harrowed..... | 5.61 | 4.64 |
| Do..... | do..... | Broadcast and harrowed..... | 5.91 | ..... |
| Do..... | do..... | Corn planter..... | 2.05 | 1.70 |
| Northwestern Wyoming..... | do..... | Broadcast..... | 12.26 | ..... |
| Do..... | do..... | Seed spot..... | 14.09 | 5.18 |
| Southern California..... | Western yellow pine..... | Broadcast and dragged..... | 8.35 | ..... |
| Do..... | Jeffrey pine..... | Broadcast and double harrowed..... | 7.90 | ..... |
| Do..... | do..... | Seed spot..... | 8.52 | 7.04 |
| Eastern California..... | Sugar pine..... | do..... | 4.65 | 6.84 |
| Eastern Oregon..... | Norway spruce and European larch..... | do..... | 3.42 | 2.82 |
| Northwestern Washington..... | Douglas fir..... | do..... | 2.91 | 4.28 |
| Northern Oregon..... | do..... | Broadcast..... | 5.68 | ..... |
| Western Oregon..... | do..... | Seed spot..... | 4.77 | 3.94 |

TABLE 8.—*Cost per acre and per 1,000 trees of planting different species in different regions by various methods.*

| Region. | Species. | Class of stock. | Method. | Cost per acre. | Cost per 1,000 trees. |
|--------------------------|-----------------------|-----------------|----------------------------------|----------------|-----------------------|
| Southern Montana..... | Douglas fir..... | 1-1 | Spade hole..... | \$15.01 | \$12.40 |
| Do..... | do..... | 2-0 | do..... | 15.58 | 12.88 |
| Southwestern Montana.. | Western yellow pine.. | 1-1 | Mattock holes..... | 4.61 | 9.53 |
| Do..... | Western larch..... | 2-0 | Ax, slit method..... | 7.45 | 13.85 |
| Do..... | Western yellow pine.. | 2-0 | do..... | 3.36 | 6.94 |
| Do..... | do..... | 1-1 | do..... | 10.04 | 16.60 |
| Do..... | Western larch..... | 2-1 | do..... | 10.22 | 18.77 |
| Central Montana..... | Douglas fir..... | 2-0 | Pick holes..... | 12.15 | 15.62 |
| Southern Montana..... | do..... | 1-1 | Mattock holes..... | 9.71 | 12.63 |
| Do..... | do..... | 2-0 | do..... | 5.10 | 7.01 |
| Western Montana..... | Western yellow pine.. | 1-2 | do..... | 9.97 | 12.93 |
| Do..... | Engelmann spruce..... | 3-0 | Ax, slit method..... | 5.10 | 7.55 |
| Do..... | do..... | 3-0 | Mattock holes..... | 7.15 | 9.41 |
| Southern Montana..... | Lodgepole pine..... | 2-0 | do..... | 15.25 | 10.00 |
| Do..... | Douglas fir..... | 2-0 | Mattock holes, slit method.. | 4.08 | 8.16 |
| Central Montana..... | Western yellow pine.. | 1-1 | Pick, slit method..... | 7.04 | 10.35 |
| Do..... | do..... | 2-0 | do..... | 5.35 | 7.87 |
| Southern Montana..... | Douglas fir..... | 2-0 | Mattock holes in plowed furrows. | 16.16 | 8.40 |
| Nebraska..... | Jack pine..... | 1-1 | Field trenches..... | 9.61 | 7.69 |
| Do..... | Western yellow pine.. | 2-1 | do..... | 15.41 | 9.78 |
| Do..... | do..... | 1-1 | do..... | 10.09 | 6.40 |
| Southern Idaho..... | Douglas fir..... | 2-0 | Mattock holes..... | 11.39 | 11.39 |
| Central Utah..... | do..... | 2-1 | do..... | 12.77 | 12.77 |
| Southern Idaho..... | do..... | 2-0 | do..... | 14.05 | 11.67 |
| Southern California..... | Jeffrey pine..... | do..... | do..... | 16.70 | 16.70 |
| Northern California..... | Western yellow pine.. | 1-1 | do..... | 19.10 | 27.28 |
| Northern Oregon..... | Douglas fir..... | 1-1 | do..... | 8.25 | 12.20 |
| Northern Washington..... | do..... | 1-1 | do..... | 8.78 | 12.91 |

For the greater proportion of reforestation operations conducted on a large scale, the cost of direct seeding can be kept within from \$4 to \$6 and planting within \$10 per acre, provided a spacing of 8 by 8 feet is followed. Under more favorable conditions these operations have been carried on at a lower cost.

Further reductions will be brought about in the future. The production of nursery stock will undoubtedly be cheapened. The development of more rapid but efficient methods of sowing and planting or of trees better suited for planting by the rapid methods already in vogue, is quite possible. In many cases the speed of planting can be increased through the use of more adaptable tools kept in the best working condition. Reductions may also be effected through larger assignments which will permit more thorough organization of the work; through confining the planting on a particular Forest at a certain season, to an individual watershed rather than conducting it on several, thus avoiding the duplication of camps, crews, and supervision; and in some cases through allotting fewer species and kinds of stock for use during a particular season.

SEASON.
PLANTING.

The chief factor governing the choice of the planting season is the climate, and this principally in its relation to the soil moisture at the period of and for a time following the planting operations. Lack of sufficient soil moisture during the period closely following planting and before the stock becomes well established is responsible for a large proportion of the mortality which occurs in plantations on the National Forests. This is particularly true for species natural to the region and normally hardy on similar sites. When planting operations are extensive, it is often necessary to conduct them during both fall and spring because the period suitable for planting is not long enough in either season for their completion.

SPRING PLANTING.

Where sufficient rainfall occurs during the spring and early summer months, the spring is almost unquestionably the logical time for conducting planting operations. The soil is in good condition; the planting operations will not normally be hindered for any great length of time by newly fallen snow; the plants will be in no danger of heaving or winter killing; and they will have a considerable period in which to become partially established before the advent of hot, dry weather. On the other hand, the stock for planting may have started growth in the nursery before the planting site is in a condition to receive it; and labor is more difficult to obtain than at other seasons of the year.

SUMMER PLANTING.

Summer is the rainy season in some parts of the country, and as the soil is in the best condition for the growth of plants it might be thought that this would be a favorable time for field planting. Up to the present, however, summer planting has been found to have few points which make it commendable. Under normal conditions trees are in an active growing state during the summer, and the field planting of growing stock is almost certain to meet with failure. It would seem that stock held in cold storage or held back in the nursery by mulching might be planted successfully, but such plantings with western yellow pine in Arizona and New Mexico have been unsuccessful on the whole. The trees have usually died during the following fall and winter. Field planting of potted trees during the summer has been partially successful with $1\frac{1}{2}$ -0¹ western yellow

¹ The first figure indicates the number of years plants remain in seed beds; the second figure, the number of years in transplant beds.

pine in New Mexico and probably offers the only reasonable chance of success in summer planting. As such plants are unduly expensive to grow and plant, the possibilities of successful planting during the other seasons should be exhausted before resort is had to this method. If summer planting could be carried on successfully in such regions, it would have the decided advantage of favorable weather conditions for a considerable period of time.

FALL PLANTING.

The possibilities of fall planting are governed largely by soil and climatic factors. Loose, friable soil, not subject to serious heaving, or even heavier soils which will be covered with a heavy fall of snow all winter, may be safely planted in the fall, provided the soil moisture conditions make this season seem the best for planting. Labor is usually readily available, and in some regions the weather continues fair and is better suited to planting than any other season. Further, the stock is in the ground, the soil becomes well packed around the roots, and the tree is ready to begin growth early in the spring. In consequence, it becomes fairly well established before the advent of the dry, hot season. On the other hand, on heavier soils or where heavy snowfall does not prevail, particularly on south and west slopes, the plants are liable both to heaving and to winter killing, and in some regions the work is very likely to be interrupted or entirely stopped by premature heavy snowfall or freezing of the ground.

One serious objection has arisen to fall planting of Douglas fir at high altitudes in Utah, where the snowfall is very heavy. The weight of the snow has crushed down the planted stock and resulted in its blackening and rotting as though attacked by a fungus. Where the plantations are under an aspen cover, the aspen leaves fall upon the small plants, become matted over them, and contribute to their destruction.

WINTER PLANTING.

Where the winter is accompanied by snowfall or by cold, freezing weather, planting is obviously impracticable. It is practiced somewhat in southern California during December and part of January before freezing occurs, along the coast region of Oregon until January 1, and during January and February in southern New Mexico.

SEASON FOR PLANTING IN DIFFERENT REGIONS.

Experience gained so far in the Forest Service indicates that early spring planting should be followed in Montana, Idaho, Colorado, Wyoming, Nebraska, South Dakota, Michigan, Minnesota, Arizona,

New Mexico, northern California, Washington, Oregon, and Utah. In southern California only, on account of the long, dry season so closely following the spring planting season, planting in the fall after the beginning of the rains is considered best.

SOWING.

The time of year when seeding should be done varies with the climate and, to a less degree, with the species. The important thing is to vary the time of sowing with climatic conditions, so that the seedlings will get the greatest possible supply of moisture. In general, tree seed should be sown immediately preceding or at the beginning of the characteristic period of precipitation in the region. Exception to this rule may be necessary on account of peculiarities of certain tree species or local abundance of rodents.

FALL SOWING.

Fall sowing is advantageous for species whose seed normally germinate slowly, such as white pine, the true firs, Douglas fir from the Pacific coast, western yellow-pine seed from Idaho or California, and seed which deteriorate rapidly, such as incense cedar. In regions where part of the precipitation comes in the form of snow and where after its disappearance in the spring a hot, dry period of several weeks or more follows, fall sowing is advisable. Fall-sown seed germinate earlier in the spring than others, and the plants have a better chance to establish themselves before the drought becomes severe. Danger of destruction of seed by rodents is not so great, because there is usually an abundance of natural foods during this season, but subsequent depredations by rodents during the winter may be very severe. In general, fall sowing is preferable on areas which will be snow covered all winter.

WINTER SOWING.

Sowing on the snow in late winter and early spring has the same effect of inducing early germination as fall sowing. Its chief disadvantage is that broadcasting is the only feasible method. Further, seed when first sown on snow are conspicuous and likely to be eaten by birds, though after a day or two of sunshine they disappear. They also sometimes slide along the surface of the snow, and, consequently, can not be distributed evenly.

SPRING SOWING.

Spring sowing has the advantage of not exposing seed to premature fall germination, to unfavorable winter weather conditions, or to destruction by birds and rodents for a period longer than is necessary.

It has the disadvantage that the seed often fail to germinate until the following year, or until about the beginning of the dry season, when the seedlings have little chance of surviving.

SUMMER SOWING.

Summer sowing is very generally inadvisable, except possibly in those regions, such as Arizona and New Mexico, which are characterized by a rainy period beginning in July. Even in these regions summer-sown seed have only a short growing period after germination and are very likely to be harmed by early frost.

SEASON FOR SOWING IN DIFFERENT REGIONS.

While sowing has not proved satisfactory in general at any particular season, experience gained so far in Forest Service operations indicates that the best results may be expected from early spring sowing in Montana, Wyoming, and Colorado east of the Continental Divide, the Black Hills of South Dakota, and possibly the Lake States. Similarly, the indications point to fall as the best period in Colorado, Wyoming, and Montana west of the Continental Divide, Idaho, Arizona, New Mexico, Utah, California, Washington, and Oregon.

FIELD ORGANIZATION.

The sowing of a certain area or the planting of an assignment of trees involves the problem of doing a definite amount of work on selected sites while certain conditions prevail. In the fall, planting must be done after the soil has become sufficiently moist and before winter sets in; in spring, shortly after the snow goes off and before the summer begins. It is important, therefore, to learn beforehand just what field organization will be necessary to complete the work in the time that is available.

CREW.

The number of men desirable will depend largely upon the scope of the operations, the length of the season, the method followed (whether it be a slow or rapid one), the topography and cover of the site, and the nature of the supervision possible. Because of the limited length of the planting season, the possible interruptions through short spells of bad weather, and the deterioration of the planting stock when heeled in at the planting site for any considerable period, the crew should be as large as is consistent with efficiency and proper supervision. Crews generally consist of from 6 to 24 men each, although much larger ones may be employed. In very rough, mountainous country or on areas covered with much brush or down timber, where

difficulty is experienced in getting around, the crew, in order to be worked successfully as a unit, should be small; but in open, rather gently rolling country, much larger forces may be worked and still be given the supervision necessary.

If possible, local men should be employed in the work. As a rule, they are not only more industrious than the transient laborers but more efficient, and they take an interest in the success of the operation. If the same men can be secured year after year, it will be found that they will become more rapid and efficient and more and more interested in the success of each year's operations. Men continuously indifferent or careless, who evince no disposition to improve, should be dismissed from the crew.

The wages will necessarily have to follow pretty closely those offered for other classes of work in the region. A graduated scale will sometimes prove effective in holding men for a longer period than they would otherwise stay. Thus they may be paid at the rate of \$2 per day if they work for from one to two weeks, \$2.25 if they stay for from two to four weeks, and \$2.50 if they remain until the work is finished. If it can be avoided, wages should not be at the rate of so much per day and board, or at least the board should be deducted for days or portions of days that the men do not work. If this precaution is not taken, there will be found men in nearly any camp who will lay off from work at the slightest provocation as long as they obtain free meals.

ASSIGNMENT OF CREW.

In seed spotting, where a portion of the crew prepares the spots and the other portion sow the seed, it is almost always true that one man sowing can keep pace with two or more men preparing spots. On the Arapaho National Forest, the ideal crew is considered to be 2 seeders to 10 men with hoes. One of the seeders is in charge of the crew and keeps the men moving. They are worked in just as long rows as can be laid out across the seeding areas in order as much as possible to avoid the delay which occurs each time that a crew reaches the end of a row. Following this system, a crew of 12 men average from 2,200 to 2,300 spots each per day. On the Black Hills National Forest it has been found that if each man prepares seed spots and sows the seed also, about one-fourth more ground can be covered per day than with any other scheme tried there.

In planting, crews are worked in a number of different ways. When the field-trencher method of planting is followed, two men handle the team and plow and pay attention to getting the rows spaced properly and parallel to each other. They are followed closely by the teamster with the trencher, who takes care that the

trench is plowed to the full depth and is so located in the furrow that dry top soil does not fall into the trench and thus come into contact with the roots of the trees. The planting crew follows and put the trees into the trench before it has an opportunity to dry out.

When the planting holes are prepared by hand, one man may do the digging and be followed by another man who plants; one man may prepare the holes for two planters; two men may prepare holes for one planter; or one man may do both the digging and the planting. Standardization of methods is hardly possible because of variations in the nature and condition of soils, and difference in personal adaptation, and in the character, size, and root systems of the stock. The practice of having certain men dig and others plant gives the officer in charge the opportunity to assign to these tasks the men best qualified for them. In soil easily worked and in country where little difficulty is experienced in getting over the ground, a combination of one digger to a planter or even one digger to two planters when the planting is carefully done will be found to work very well. In very rough country where the preparing of the holes is difficult and slow, one planter may be able to follow two diggers. In general, however, it is thought that in such country or where there is a dense ground cover of logs or brush, each man should prepare the holes and plant the trees also. This obviates the necessity of two men traveling over the same course; and actual practice in Districts 1 and 6 has shown it to be by from 25 to 30 per cent the most rapid method under such conditions.

The practice is sometimes followed of having one or more people carry the trees and distribute them to the planters as they are needed. Boys can be employed at this task at a lower wage than the men receive, or the man in charge of the crew can perform this duty. Men engaged in distributing only will be idle part of the time; they will have calls for trees from two or more planters at the same time and obviously can not supply all of them at once, and if the trees are distributed in advance of the planters the roots may be exposed long enough to dry them out. Under most circumstances, one man can carry his own trees and plant as fast as another man can dig, the trees are at hand just when he wants them, and the roots are not exposed until they are ready to go into the hole.

When some of the men are assigned to planting and others to digging, it is well to have them change off two or more times a day if it can be done without impairing the quality of the work. It will relieve the monotony and may promote the rapidity of the operation.

One man who acts as the leader of a crew should set the pace and direct the course of the rows. The others keep abreast of him, and, to facilitate rapid work, merely estimate the proper distance between the holes. Considerable latitude should be allowed in locating the

holes in order to take advantage of any shade offered by rocks or brush or of small areas where the soil is particularly good. These points are of special importance on inhospitable sites.

The planter should follow the digger closely, since this will promote rapidity of work and lessen the possibility of the holes drying out or of missing some of them entirely. The planters should carry their trees in a manner which will preclude the possibility of the roots drying out. Carrying the trees in a bucket with the roots immersed in a puddle made of clay and water is not desirable. The puddle so mats the roots together that they are not well distributed in the planting hole. If the roots are immersed in clear water the effect is somewhat the same. At present the most common, and it is thought the most effective, plan is to carry the trees with the roots surrounded by wet burlap or covered with damp moss. Only lots sufficient to last from one to two hours should be packed around. Large lots are burdensome, the burlap becomes dry, and then the roots. Larger lots of trees, properly stored, should be available at different points on the planting site, from which the planter can replenish his stock when necessary. Water should be on hand also, so that the burlap or moss can be wet occasionally.

SUPERVISION OF CREWS.

The necessity of constant supervision in field planting and seeding can not be emphasized too strongly. Unless it is given, the efforts spent in producing and planting the trees may be entirely lost, for in no other part of the work does the result of carelessness show so clearly. If any of the essential points for successful planting are slighted, the chances of success are greatly reduced at the outset. The technical men can well be employed in supervision only, and the better and more experienced workmen may be made foremen at a higher wage and be charged with supervision. Experience indicates that there should be one man charged with supervision for each crew of from 6 to 10 men. Forest officers, however, should inspect the quality of the work and direct the foreman as to the details.

EQUIPMENT.

Field planting and sowing necessitates the carrying in stock of considerable equipment for use in actual operations and of tools necessary to keep this equipment in shape.

SOWING TOOLS.

The tools most commonly used in preparing the ground for sowing are the mattock, grub hoe, garden or some slightly heavier and more strongly constructed rake, and hazel hoe. The mattock and grub hoe

are best where the soil is heavy or rocky or where it is desired to stir it to a considerable depth; the rake is good in loose soil where there is not a heavy cover of grass and where deep cultivation is not necessary; and the hazel hoe is good where the soil is not very rocky or exceptionally heavy.

Another seed planter (Pl. IX, fig. 1) has recently been designed which gives promise of being a good tool for this work where the sod is not too heavy. Its construction in principle is that of a removable soil-preparing tool such as the mattock, rake, or hoe, attached to a hollow iron handle, which serves as a receptacle for seed. Through a system of openings at the lower end of the handle which are opened and closed by means of a sliding rod and lever operated by one hand of the worker, the seed are distributed on the spot as it is prepared with the rake or hoe attachment. By continuing the operation of raking or hoeing, the seed can also be covered. In an experimental trial it has proved more rapid than the common garden rakes, but not quite so rapid as the corn planter. One man prepared 4,830 spots per eight-hour day. When using small seed (lodgepole pine) it has proved much more economical of seed than the corn-planter method or that of scattering seed by hand on the seed spots. Its weight of about 5 pounds when empty of seed is an advantage in preparing spots in heavy or sodded soils, but becomes burdensome to the operator. Fairly clean seed is necessary, as the presence of foreign matter larger than the seed itself is likely to prevent successful operation of the tool.

In the trials which have been made of the tool some imperfections have been noted. A portion of the large seed is likely to be cut. In a trial given it with maritime-pine seed, about 5 per cent were injured in this manner. Small seed are injured very little, if any. The tool has not been found as satisfactory as the mattock in heavy turf. It has been found that the seed can not be scattered satisfactorily at the same time as the tool is being drawn toward the operator, unless it is carefully handled, because the seed before striking the ground is struck by the tool itself and scattered outside of the prepared spot.

Numerous corn planters have been tried, and there are several objections to the use of those commonly found on the market. Some have a soft snout, which is knocked out of shape by rocks and is constantly in need of repair, some can not be adjusted to sow the proper amount of seed or to sow it at the right depth, some are not strongly enough constructed to hold together under the rough usage which they get, and some are so heavy as to be cumbersome.

PLANTING TOOLS.

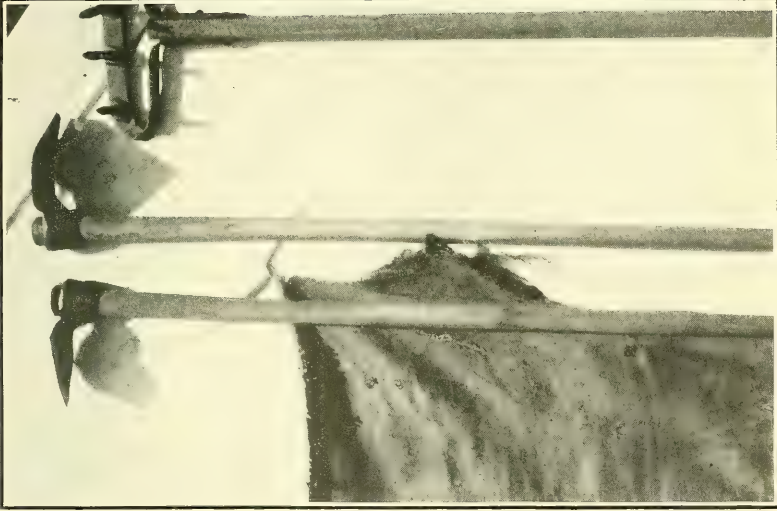
The planting tool most commonly used on the National Forests is some type of the grub hoe or mattock. The spade, ax, and field trencher are used only slightly. Various modifications of the common type of mattock and grub hoe found on the market have been tried. The blades have been narrowed and lengthened; they have been bent so as to form a right angle with the handle, which has been thought desirable for planting on slopes; handles with a slight S curve have been used instead of the common, straight ones; mattocks, one of whose blades is a pick, have been found efficient in heavy, rocky soil; and tools with shortened handles have proved satisfactory in loose soils, where each man of a crew digs the hole and plants the tree also. In most planting operations a mattock with a blade from 10 to 12 inches long seems desirable. For all varieties of soils and conditions encountered these are unquestionably the most efficient planting tools. They are sufficiently heavy to be used without bending or breaking in any soil where planting is at all practicable, and they can be used in the hole, slit, or grub-hoe method of planting. The mattock has a cutting edge which is useful in severing roots, and its blade is efficient for tamping the soil around the plants.

The spade is the next most efficient planting tool. In very loose soil it serves better than any other, either in the slit or the hole method of planting. On very hard, heavy, rocky, or gravelly soils it can not be used to good advantage and sometimes not at all. The short-handled tools are preferable, but any of them are likely to break eventually either in the blade or in the shank.

On the Pike National Forest a planting bar has been devised for work on rocky areas where the grub hoes could not be used advantageously. The bar consists of a steel shank 10 inches long $\frac{1}{2}$ inch thick, 2 inches wide at the point, and 4 inches wide at the shoulder inserted in a $1\frac{1}{4}$ -inch hollow handle. The entire weight is 12 pounds. After one season's work it is declared to be, for such areas, a decided improvement on the grub hoe.

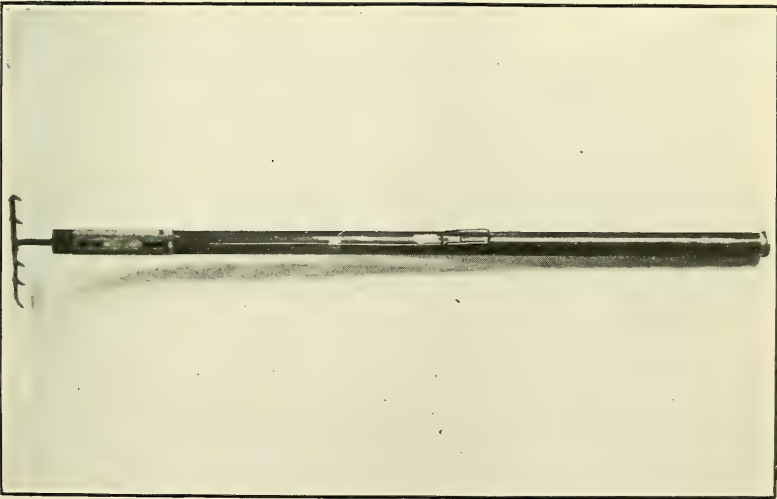
The ax can be used only in the slit method of planting in loose soil or in heavier soil which is free from rocks and not covered with turf. It can not be used successfully in rocky soils. It is not considered desirable nor recommended under any circumstances because the cleft made with it is not sufficiently deep to accommodate fully the roots of most stock used in field planting. Where this method has been followed, the handle has been cut off to a length of about 20 inches.

Weight is an important consideration with any tool in securing efficient work, and especially in increasing the rate of work. A certain number of motions are necessary in clearing off the surface of the ground, digging the hole, and working up the soil, whether



F-10253A

FIG. 2.—PLANTING AND SOWING TOOLS: HAZEL HOE, GRUB HOE, AND HEAVY RAKE.



F-13000A

FIG. 1.—ECKBO SEED PLANTER.

a heavy or a light tool is used. The extra energy exerted with a heavier tool can well be expended in performing more work, and under most conditions met in planting it will be found that a tool of medium weight, about 4 or $4\frac{1}{2}$ pounds, will be preferable to a heavier one. Short-handled grub hoes, $2\frac{1}{2}$ to 3 pounds in weight, are now being used successfully in some of the Idaho planting.

OTHER EQUIPMENT.

A very serviceable basket for field planting has been devised at the Nebraska Forest. This is described as follows:¹

The Besley planting basket is 12 inches wide, 20 inches long, and 8 inches deep and made of light, galvanized iron, having two handles, as a market basket, and four short legs, consisting of stove bolts 1 inch long soldered in the corners. The top is rolled over a No. 12 wire to give strength. For the inside of the basket several thin quilted pads are furnished. These are fastened on vertical wires at one end, and the trees are placed in layers between the moistened pads. This provides perfect protection for the lower layers while the upper layer is being used.

A modification of this basket has been constructed at the Bessey Nursery. The basket is made collapsible by using canvas instead of galvanized iron. It is of about the same weight, but can be packed about more readily than the first-described type.

Bags made of waterproof cloth and equipped with shoulder or belt straps have been designed in District 6 for carrying stock. The tops of the stock protrude from the bags where they can be grasped by the planter, while the roots are surrounded with wet burlap or moss. In District 1 the specifications for a similar bag are as follows:

Fourteen inches long, 11 inches deep, with a pocket $8\frac{1}{2}$ inches long and as deep as the bag, sewed on the outside. Material of heaviest duck. Waterproof lining on inside of main pocket. Two rings sewed on ends of bag for inserting $\frac{1}{4}$ -inch rope to tie around waist of planter to keep bag from swinging. Adjustable shoulder straps sewed at one end of bag and fastened with snap at other end.

One of these bags will hold about 1,000 2-0 or 600 1-2 western yellow pines. The plants are readily drawn from the small pocket sewed on the outside, which holds about 100 trees. The main pocket is used to carry the surplus.

Common 2-gallon water pails, in which the roots are immersed in water or covered with damp moss, are also used. The chief objection to them is that on slopes they tip over very readily.

The common wet burlap cover is not so good as the others mentioned, both because it rapidly becomes dry and because in pulling out one seedling for planting the roots of others are very commonly pulled out also and exposed.

¹ *In American Forestry*, Vol. XVIII, No. 5.

REPAIRS AND EXTRA EQUIPMENT.

That all tools be kept in good working order is essential because it increases the amount and efficiency of the work. A portable forge with an anvil and a grindstone or a supply of files should, if possible, be kept in the planting camps for this purpose. A number of extra tools should also be kept on hand for use while others are being repaired. If pails or baskets are used by the planters for carrying the trees, a surplus of these should also be kept on hand.

CAUSES OF FAILURE AND LOSSES, AND METHODS OF PREVENTION.

Some losses must be expected, but these will be materially reduced when the species, class of stock, sites, methods, and seasons most suitable have been more thoroughly worked out. The only factor that it will never be possible to foresee or guard against is unfavorable weather. The weather being left out of account, the important factors upon which the success of plantations depend are as follows:

SPECIES AND CLASS OF STOCK.

The safest guide in the choice of species is the trees already growing on the site or on similar sites in the same locality. The introduction of other species or the extension of natural range is always accompanied by high probability of failure. So long as there are in the aggregate such large areas in need of reforestation, the best plan at present is to rely upon the native species. The introduction of others should not be attempted unless upon a very small scale for experimental purposes. While thriving at first, such species may after a few years become very inferior in form and rate of growth.

In some instances seedlings have given better results than transplants in field planting and vice versa. Time will undoubtedly develop the fact that on some, probably the better sites in the more favorable regions, seedlings will succeed admirably. As their use will reduce costs, they should be planted under such conditions. Upon by far the greater portion of the area needing planting, however, two or three year old transplant stock, by virtue of its better developed root systems and somewhat dwarfed stocky tops, offers much better assurance of success in field planting. Even with such stock consistently heavy grading should be followed to eliminate the weak trees.

SOURCE OF SEED.

The source of seed also exerts its influence upon the final success of the plantation. Experiments have demonstrated clearly that stock from seed locally collected succeeds better than that produced from

seed collected either in a more southern or in a more northern region. The former produces trees which do not harden rapidly enough to escape danger from frost and the latter produces stock of less rapid growth.

HANDLING OF STOCK.

The manner of handling the stock from the time it is lifted in the nursery until it is planted in the field is all important. The fatal effect of allowing the roots to become dry or the tops to heat and mold has already been shown. Too much emphasis can not be laid upon this point.

QUALITY OF THE SITE.

Unfavorable sites, such as those with very thin or very rocky and sandy soils, those with a dense cover of grass or other herbaceous growth which will compete with the plants for soil moisture, wind-swept areas, or those with intense insolation, are often responsible for failure. The most favorable sites should first be chosen so far as possible; and, again, the place for each tree or seed spot should be carefully selected with reference to shelter from the sun or live stock or to take advantage of the better patches of soil.

TIME AND METHOD OF PLANTING OR SOWING.

The time of planting or sowing has much to do with success. The climate of a region may be such as practically to insure the failure of operations conducted at a certain season. This makes the study of local climatological data of considerable importance when extensive operations are to be conducted. These will indicate the seasons when the weather conditions will normally be favorable. If the soil is moist at the time of planting or sowing and the work itself is followed by a favorable season, the probabilities of success are good; while if an unusually dry summer or very open, cold winter follows, the greatest success can not be expected. This is one of the factors governing success which can not be foreseen and over which no control can be exerted. A good deal of dependence must accordingly be placed upon the quality of the site itself, and in controlling the other factors so far as possible.

The virtue of the different methods of planting and sowing has already been discussed somewhat, and it can readily be seen that where the methods employed are not suitable to the site, soil, or the stock, losses are certain to occur. Experience gained from experimental work and the character of the native stands of timber will be the best guides in determining the proper methods.

EFFICIENCY OF CREWS.

Careless work may be wholly responsible for failure in planting operations. Planting holes not dug deep enough, failure by the planters to distribute the roots well, bending the roots, insufficient packing of the soil or the packing of dry soil around the roots, undue exposure of the roots during planting, poor supervision—these and possibly other factors will contribute largely to failure. Speeding up the operation in order to make a record is often directly responsible for carelessness. No worse mistake can be made. A planting crew should not be allowed to loaf, but neither should it be urged to such efforts that the thoroughness of the work will suffer. Much loss in past planting has without question been due to this cause. Excessive speed will result in the planting of a larger acreage, but not in its successful planting, and judgment concerning an operation must in the end be based upon its success. Further, where partial failure follows such work the expense of replanting the area plus the first expense will much more than equal the expense of more careful initial operations. Good, efficient crews doing careful and conscientious work at a reasonably rapid rate will do much to make a planting successful and to keep the costs within reasonable limits.

PROTECTION.

Plantations can easily be killed by fire and damaged by stock, insects, disease, and rodents. Fire danger is, of course, always possible, and where it is very acute, reforestation should not be attempted unless adequate fire patrol can be afforded. Reforestation, moreover, need not yet be carried on where roads or trails do not make the area easy of access by fire-fighting crews.

FIRES.

Fire guards are constructed to assist in protecting plantations. On the Nebraska National Forest (Pl. X) these consist of two strips of plowed ground each 12 furrows wide paralleling and separated from each other by a strip of unplowed ground about 2 rods wide. The cost of construction is about 50 cents per mile per furrow. These plowed strips are harrowed when necessary to keep down subsequent growth and the intervening strip of unplowed ground is burned over. Under most conditions met in reforestation, fire-breaks around plantations will be unduly expensive and therefore impracticable. Ordinarily, fire is a risk which will have to be assumed in any plantation.



FIRE LINES ON THE NEBRASKA NATIONAL FOREST.

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STOCK.

If large areas are to be reforested, stock should be excluded, and, if possible, sheep should be excluded from any plantation as they do more damage to coniferous plants than any other animal, goats excepted. As a rule, cattle do not damage plantations much, provided the ground is not plowed, the area is not close to salting and watering places, and the stock is not permitted to concentrate too much in particular localities. Fencing against live stock is seldom advisable, and where exclusion is necessary it should be based upon natural boundaries.

INSECTS.

The pine-tip moth has damaged plantations in Nebraska, and the white grub of the June beetle cuts off the roots of young planted stock in the southwest. No practicable method of combating these insects over large areas has been devised.

Grasshoppers have destroyed whole plantations on the old Kansas National Forest, attacking both hardwoods and conifers. Methods of control of these insects through burning, poisoning, and trapping have been worked out in California,¹ but it seems that certain methods are effective only with certain species, and control measures must accordingly be worked out for each region.

DISEASES.

Diseases in plantations on the National Forests have not been at all serious. Were dangerous diseases to appear it might be impractical as well as impossible to stamp them out. It is well, therefore, to warn against the planting in one general region of nursery stock grown in another unless there is absolute certainty that it is not affected by diseases which may prove harmful to the native timber where the stock is to be planted. White pine grown in regions where the white-pine blister rust is prevalent should not be planted in the western white pine and sugar pine regions; and western yellow-pine nursery stock produced in a region where mistletoe is present should not be shipped, for instance, to the Black Hills where this disease does not occur. Great economic losses are possible through the shipment of diseased or insect-infested stock.

RODENTS.

Young planted stock is often damaged by rodents, and tree seed is very attractive to them. In many cases it is their natural food, and

¹ Cal. Agri. Exp. Sta. Bul. 170, "Studies in Grasshopper Control."

they are wonderfully diligent and expert in searching it out. Many experiments in the direct seeding of hardwoods and conifers have failed because nearly all of the seed was eaten by mice, chipmunks, and other animals. Where tree seed attractive to rodents is to be sown it is necessary, therefore, to consider the systematic poisoning of the area as an essential operation. In numerous experiments conducted by the Forest Service, seed spots have been sown and then covered with small portable screens which effectively protected them from rodents and birds. The successful germination in these spots and the absolute failure in similar unprotected spots adjacent showed how important an adverse factor animals, and possibly birds, are in reforestation.

In the spring of 1910, in cooperation with the Bureau of Biological Survey, intensive studies of the damage from rodents were conducted at a number of places where direct seeding was in progress, and on many other sowing areas observations were made by forest officers. In nearly every case a different species of animal was found to be the chief cause of damage. There are, of course, a great many species of mice, chipmunks, and ground squirrels, and a number of different kinds of tree squirrels. Each species appears to have distinctive habits, and the food and activities of the same species differ greatly with the time of year. The kind of poison bait and the manner of applying it must therefore be adapted not only to the species of animal to be destroyed, but to its taste and activities at the time the poisoning is done. The latest approved methods of poisoning rodents shown below are those developed by the United States Biological Survey.

The poison preparation which most nearly meets all requirements is as follows:

Mix 1 heaping tablespoonful of gloss starch in $\frac{1}{2}$ teacup of cold water and stir with 1 pint of boiling water to make a thin, clear mucilage. Remove from the stove. Mix together 1 ounce of powdered strychnine (alkaloid)¹ and 1 ounce of powdered bicarbonate of soda and stir with the starch to a smooth, creamy mass. Stir in 1 tablespoonful of glycerine, and finally $\frac{1}{2}$ ounce of saccharine. Apply to 20 quarts of good clean oats or wheat and mix thoroughly to coat each kernel.

This poison is effective in destroying chipmunks, kangaroo rats, pocket mice, the smaller species of ground squirrels, and, at times, kills many white-footed mice.

Oats are generally the most successful bait. On account of the skill of chipmunks in "hulling," wheat is more effective for these animals. Barley, in the proportion of 16 quarts to each ounce of

¹ If strychnine sulphate is used, dissolve in the boiling water before adding the starch; also dissolve the bicarbonate of soda before adding to the poisoned starch. Care is necessary that the resulting mixture does not greatly exceed a pint.

strychnine, has given best results in destroying the larger "digger" ground squirrels, and is most effective during the dry summer season.

A second process of applying the poison described below is an improvement over that just described in that it delays the taste of strychnine, the intense bitterness of which is the greatest factor detracting from success in poisoning certain rodents. During the present season this poison has been used with great effect against rodents which have hitherto exhibited marked aversion to strychnine baits. The fact that the poison coating readily separates from the bait is also of importance to the success of this preparation, especially for such rodents as habitually "hull" grain. In the process of hulling, sufficient strychnine to kill the animals flakes off in their mouths. Grain poisoned in this way must be handled carefully to avoid loosening or grinding off the poison coating. It should be freshly prepared in small quantities, for use each day, as follows:

Mix together $\frac{1}{4}$ ounce of powdered strychnine (alkaloid), $\frac{1}{4}$ ounce of powdered bicarbonate of soda, a scant $\frac{1}{2}$ teaspoonful of saccharine, 2 heaping tablespoonfuls of dry powdered starch; and stir with enough cold water to make a thin paste of the consistency of cream. Apply gradually to the material to be used as bait, mixing vigorously to distribute the poison as evenly as may be and to prevent the formation of lumps.

Oats, wheat, cracked corn, and dry coarse meal of all kinds may be so poisoned. For ground squirrels, chipmunks, and medium-sized rodents generally, one-fourth ounce of strychnine is sufficient for 4 quarts of bait; for white-footed mice the amount of bait may be doubled. Among baits especially attractive to the white mice may be mentioned pine seeds (both whole and crushed seeds), roasted peanuts, crushed to a coarse meal; crushed wheat; and mixtures of crushed or chopped grains.

In the work as usually done on woodland planting areas, each quart of the poisoned grain is sufficient for 60 or more baits. The baits should be placed in slightly scattered form along logs, on stumps, on clean hard places on the surface of the ground about burrows, along the animals' trails, and especially in the dry sheltered places beneath logs, and in other locations not exposed to rain or moisture, that they may retain their effectiveness for a long time.

Poisoned baits of sweet potato almost invariably kill pocket gophers if placed in the underground runs without too much disturbance of the latter. Baits of carrot or parsnip may be substituted, or corn, poisoned as in the first formula described, but none of these are so completely successful as sweet potatoes.

The baits of vegetables should be cut about 1 inch long and one-half inch square and washed and drained. From a pepperbox slowly sift $\frac{1}{2}$ ounce of powdered strychnine (alkaloid) and one-tenth of this quantity of saccharine

(ground together in a mortar) over about 4 quarts of the dampened baits, stirring to distribute the poison evenly.

The runways, which are usually from 4 to 8 inches beneath the surface, can be located by means of a probe made of any strong handle an inch in diameter and 36 inches long. One end should be bluntly pointed. Into the other should be fitted a piece of three-eighths-inch iron rod, protruding about 12 inches, and bluntly pointed. A foot rest aids in probing hard soils. By forcing down this iron rod near gopher workings, or a foot or two back of fresh mounds, the open tunnel can be felt as the point breaks into it. The blunt end of the instrument is now carefully used to enlarge the hole, a bait or two is dropped into the run, and the probe hole closed.

One soon becomes expert in locating the runs, and a man can treat from 300 to 500 gopher workings in a day. Baits need be placed at only two points in each separate system or group of from 10 to 30 mounds, which is usually the home of a single gopher. Baits placed in open underground runs have invariably killed the gophers, and the method has found great favor wherever it has been introduced.

At the Converse Nursery, in California, wood rats or "pack" rats (*Neotoma*) have been found responsible for a considerable part of the damage to transplants usually ascribed to rabbits.

Wood rats eat little or nothing of the trees they cut, but carry the green tips into their nests to store away, as they do many other things for which they apparently have no real use. These animals are rarely killed by any of the baits which have been described, though they pack away such baits readily enough. Effective results were obtained by dusting baits liberally with finely powdered strychnine, as the rats were killed in packing them. Dry oatmeal biscuits one-half inch square and one-fourth inch thick, cut from a stiff dough of oatmeal and water after rolling it in sheets, proved to be especially successful baits. Raisins and whole corn may also be used.

Though both cottontails and jack rabbits fall victims to poisoned oats during periods when their natural food is scarce, this poison can not always be relied upon to destroy them when it is most important to check their depredations. Green or ripening grain heads of barley or wheat are among the most attractive baits in summer. Soaked for 48 hours or more in a solution of 1 ounce of strychnine sulphate and one-eighth ounce of saccharine in 2 gallons of water, such baits have occasionally proved very successful. They should be used only in locations where live stock is not endangered.

Investigations on the Pike National Forest by Forest Expert H. S. Reinsch have developed the fact that on that Forest hulled oats is the grain most relished by mice and hulled barley is the most desirable grain for poisoning all species of rodents. On the Arapaho National Forest groats is considered superior to wheat for use in poisoning.

Fencing has been tried in southern California to protect planted stock from rodents, but is quite expensive, and has not been found efficient. It has been found impossible to rid the inclosed area of them, and all destructive types of rodents, especially pack rats, can not be kept out even by fencing. Rabbits have been successfully combated on the Kansas National Forest by inserting a few grains of strychnine in garden beets and placing these on small upright stakes throughout the planted area. On the Wasatch National Forest alfalfa hay poisoned with a solution of strychnine and water has proved effective. Rabbits can also be destroyed in early spring by baiting with poisoned twigs cut from fruit trees or native brush. The twigs should be scattered a few hours before sundown along the rabbit trails or in openings on the plantations.

In distributing any kind of poisoned grain it is important to put it out of the reach of birds. Ordinarily this is not difficult. Cavities among shallow piles of stones or under roots or logs or burrows of animals will be entered by rodents and ignored by birds. Lacking these, cover made from pieces of bark, boards, or flat stones, with a low runway left beneath, will fill the purpose. Barley is usually attractive to rodents and is the grain least relished by birds. To cover an area thoroughly requires 1 bushel of poisoned barley or oats to every 40 acres, a pinch of the grain being dropped at intervals of 15 feet in rows 40 feet apart.

Red lead has been tried in protecting acorns and nuts from rodents. Its use delays germination only slightly, but the protection it gives is not thorough. Sometimes it appears even to attract birds and certain rodents. It is applied by placing the wet nuts or acorns in a bag containing red lead, and shaking thoroughly. Carbolic acid solutions and petroleum injure seed and are of doubtful value as protection from animals.

SOWING OR PLANTING BY REGIONS.

SELECTION OF SITES.

The selection of sowing or planting sites for operations on a large scale is of great importance and should be governed to some extent by the local economic development of the country, the accessibility of the sites, the labor and transportation facilities, the need for reforestation, the protection which can be given from fire, and the suitability of the sites for the operation.

The suitability of the site for sowing or planting can best be determined by experimental work, but in the absence of this by a number of other factors. Among these are the natural growth on the area, the precipitation, the exposure, the altitude, the length of

the growing season, the soil moisture, and the depth and character of the soil.

The suitability of an area is very strongly indicated by the natural growth present. This is a pretty fair criterion of the quality of the site, and it points out the species which are most likely to succeed—either those which naturally occupy the area or others whose demands upon soil and climate are quite similar. A heavy growth of trees on similar adjacent sites will indicate that the area is quite probably suitable for sowing or planting; while a sparse growth of a drought-resistant species of tree on such sites will indicate that the area is only suited to reforestation with very drought-resistant species and that even then success will be uncertain.

Locally, the amount of precipitation over various sites will differ very little at the same altitude, but regionally and at different altitudes it will vary considerably both in amount and distribution, and thus be of considerable influence in determining the suitability of a site. Precipitation in conjunction with the soil depth and character will largely determine its moisture content. This, in turn, is most influential in determining the success of properly conducted reforestation operations, provided the stock used is otherwise climatically adapted to the site. The total precipitation is not alone important. A total of from 12 to 15 inches will support a tree growth if it is distributed rather evenly throughout the growing season; but if it comes mostly during winter, for instance, and the other seasons are characterized by extreme drought, planted stock is not likely to succeed. Drought of moderate duration can be withstood by plants after they have become firmly established, but for two or three years following planting they are less able to withstand any protracted dry period.

The depth and character of the soil are important in conjunction with precipitation. Deep, fine, retentive soils, by virtue of their water-holding capacity, or even looser surface soils with retentive subsoils at a depth of from 2 to 3 feet, offer better conditions for planting than loose, sandy, gravelly, or rocky soils which drain rapidly and soon become dry, or even soils of finer texture which are very shallow and soon dry out for that reason.

Exposure is of influence chiefly in its relation to soil moisture. South and west slopes become much hotter than north and east slopes; and, other conditions being equal, evaporation is much greater from the former and drought condition more prevalent. Further, on south and west slopes the snow may melt during the winter and planted stock will be in danger of drought or winter killing during that period. Moreover, on these slopes growth starts earlier in the

spring and continues later in the fall, thus subjecting the plants to greater danger from either early or late frosts.

The relation of altitude to the suitability of a planting site is found in its influence upon precipitation, humidity, evaporation, soil moisture, accessibility, and length of the growing season. With increase in altitude, there is normally an increase in and a better distribution of the precipitation, the relative humidity is greater and evaporation less, the soil moisture is greater, the region is usually less accessible, and the length of the growing season is shorter. The intermediate altitudes within the natural limits of any particular species of tree offer the most favorable climatic conditions for its successful planting. High altitudes are usually difficult of access; and unless the stock for planting is grown at a similar elevation it will not be in a condition for setting out at the time when the operation should be conducted. Stock grown in nurseries at a lower altitude will start growth in the spring before planting can be carried on at higher altitudes, and it will not be hardened sufficiently for fall planting by the time it is needed.

The immense total acreage on the National Forests in need of planting, the cost of the operation, and the necessity of securing satisfactory results make it highly desirable to plant the better sites first. Planting at best, under the conditions encountered and with the employment of unskilled and usually uninterested laborers, is always of doubtful success. The selection of the better sites, however, will mean that a larger proportion of the planted trees will live; they will make better growth after becoming established and form a better stand at maturity; and much experience in regard to methods of planting and the most desirable classes of stock will be gained. The poorer sites can be planted later when cheaper stock, cheaper labor, and better methods make it more feasible.

Although results do not yet permit a final judgment in regard to the comparative suitability of different sites on the National Forests of the West for planting or sowing or of the best class of stock to be used, an attempt is here made to classify them in the order of their favorableness. It must be remembered that in this classification of sites the altitudes given are not exact; that they change with latitude; and that the best planting and sowing sites are almost without exception found at elevations somewhere between the extremes.

Experience will undoubtedly lead to a change in the order in which these sites are listed and may prove some of them unfitted for planting or sowing. There are other sites which because of their unfitness or for other reasons are not considered for reforestation.

Among these are areas either above or below timber line, rock slides, very shallow-soiled south slopes, wet alpine meadows, very dense brush fields where it is a physical impossibility to conduct planting operations, and areas now barren but which it is almost certain will eventually be stocked from surrounding seed trees.

MONTANA AND IDAHO.

East of the Continental Divide no direct seeding is recommended, except possibly on the most favorable north slopes, with the best quality of soil, and here only on an experimental basis. West of the Continental Divide direct seeding is not generally recommended; but the best chance for success is thought to be with white and yellow pine on cool north slopes. Recent burns are preferable, since there the loss from rodents and damping off is diminished.

In general, planting may be carried on with success practically anywhere within natural altitudinal limits west of the Continental Divide. East of the Divide sod-covered areas should not be planted.

EAST OF THE CONTINENTAL DIVIDE.

Western yellow pine: (1) South slopes, altitude of from 3,500 to 6,500 feet; (2) west slopes, altitude of from 3,500 to 5,500 feet; (3) east slopes, altitude of from 3,000 to 5,500.

Such ground cover as grass, weeds, brush, and fire débris have an appreciable effect on success by reducing transpiration; but the greatest cause of success or failure east of the Continental Divide is believed to be porosity of soil. Soil with clay content enough to make it pack hard invariably results in heavy loss. The best sites are those with soil which contains particles of rock large enough to prevent close packing. Such soil is usually indicated by a thin broken sod.

Douglas fir: (1) North slopes, altitude of from 5,000 to 7,500 feet; (2) east slopes, altitudes of from 5,000 to 7,500 feet; (3) west slopes, altitude of from 5,000 to 6,500 feet. The effect of ground cover on the success of Douglas-fir plantations is greater than on those of western yellow pine.

Lodgepole pine: (1) North slopes and high divides, altitude of from 6,000 to 7,500 feet; (2) east slopes, altitude of from 6,500 to 7,500 feet; (3) west slopes, altitude of from 6,500 to 7,500 feet.

WEST OF THE CONTINENTAL DIVIDE.

Western white pine: (1) North slopes and flats up to 4,500 feet in elevation (on the Bitterroot Mountains up to 5,000 feet); (2)

east, northeast, and northwest slopes up to about 4,000 feet. On either of these situations the best results are obtained in deep, loose soils, free from rock.

Western yellow pine: (1) South slopes up to 4,000 feet (on the Bitterroot Mountains up to 5,500 feet); (2) southeast and southwest slopes up to 3,500 feet.

Douglas fir: North slopes up to 6,000 feet.

Western red cedar: Favorable north and northwest slopes in mixture with western white pine up to 4,500 feet.

Engelmann spruce: (1) North slopes from 4,000 to 5,500 feet. In mixture with other species on north slopes from 3,500 feet upwards; (2) east and west slopes from 4,000 to 5,500 feet.

Western larch: (1) North slopes from 4,000 to 6,000 feet. In mixture with other species on north slopes from 3,500 feet upwards; (2) south, east, and west slopes from 4,000 to 6,000 feet.

COLORADO, WYOMING, SOUTH DAKOTA.

Western yellow pine: Between altitudes of 5,300 and 8,500 feet, the sites in order of their favorableness are: (1) all aspects of burns or cut-over areas, for the most part devoid of vegetation, which have failed to restock naturally even though soil and moisture conditions are normal; (2) all aspects of burns and cut-over areas with a well defined cover of aspen; (3) all aspects of burns and cut-over areas of long standing, with or without aspen, where moisture and soil conditions are normal, though such sites are almost invariably overgrown with a heavy cover of sod, grass, and weeds; (4) all aspects of open, grassy parks without trace of any former timber, where moisture conditions are normal and the soil is of good depth; (5) north and east aspects of open parklike areas without traces of former timber, often found in the yellow pine and in the lower limits of the Douglas-fir types, supporting dense stands of oak brush and occasionally lone, stunted balsams but with moisture both of air and soil deficient; (6) north aspects of low foothill, brush, and sagebrush areas in the lower limits of the yellow-pine type where yellow pine, pinon, juniper, and sagebrush may be associated.

Sowing should be attempted only on the north and east aspects of sites 1, 2, and 3 in the Black Hills region of South Dakota.

Douglas fir: Between altitudes of 8,200 and 9,400 feet, the sites in order are: (1) all aspects of burns or cut-over areas, for the most part devoid of vegetation, which have failed to restock naturally even though soil and moisture conditions are normal; (2) all aspects of burns and cut-over areas with a well-defined cover of aspen; (3) north and east aspects of burns and cut-over areas of long standing,

with or without aspen, where the moisture and soil conditions are normal, though such sites are almost invariably overgrown with a heavy cover of sod, grass, and weeds; (4) north and east aspects of open grassy parks without trace of any former timber, having normal moisture conditions and soil of good depth; (5) north aspects of open parklike areas without trace of former timber, often found in the yellow pine and lower limits of the Douglas-fir types, supporting dense stands of oak brush and occasionally lone, stunted balsams.

Sowing should be attempted only on north and east aspects of sites 1 and 2.

Lodgepole pine: Between altitudes of 8,500 and 10,300 feet the sites are: (1) All aspects of burns or cut-over areas, for the most part devoid of vegetation, which have failed to restock naturally even though soil and moisture conditions are normal; (2) all aspects of burns and cut-over areas with a well-defined cover of aspen; (3) all aspects of burns and cut-over areas of long standing, with or without aspen, where moisture and soil conditions are normal, though such sites are almost invariably overgrown with a heavy cover of sod, grass, and weeds; (4) all aspects of open, grassy parks without trace of any former timber but with normal moisture conditions and soil of good depth.

Sowing is advisable only on sites 1 and 2, and planting is usually necessary only on sites 3 and 4.

Engelmann spruce: Between altitudes of 9,500 feet and timber line, the planting sites in order are: (1) All aspects of burns and cut-over areas, for the most part devoid of vegetation, which have failed to restock naturally even though soil and moisture conditions are normal; (2) all aspects of burns and cut-over areas with a well-defined cover of aspen; (3) all aspects of burns and cut-over areas of long standing, with or without aspen, and usually overgrown with a heavy cover of sod, grass, and weeds; (4) all aspects of open grassy parks without trace of former timber but with soil of good depth and with normal moisture conditions. Only one site is thought possible for sowing, that being the north aspect of site 2.

NORTHERN MINNESOTA AND MICHIGAN.

Eastern white pine: Only one type of area is considered as a planting site for this species, namely, all aspects of burns and cut-over areas with natural white pine reproduction wanting, with numerous species of deciduous trees and shrubs present and with normal moisture conditions and soil of good depth, usually composed of light sand over a heavy clay subsoil.

Norway pine: The only type of area considered for this species is all aspects of burns and cut-over areas with natural reproduction of desired species wanting, usually with numerous species of de-

ciduous trees and shrubs, and with soil of nearly pure sand to a great depth and somewhat lacking in moisture. Dry rocky ridges and exposed slopes are included.

Jack pine: Only one type of site is considered for this species, namely, all aspects of dry areas of pure light sand of unknown depth which may or may not have previously borne commercial species. It may bear a light cover of grass and weeds or may include undesirable deciduous trees and shrubs. The soil may become very dry.

Sowing is not considered advisable with any of these species.

NEBRASKA SAND HILL REGION.

Jack pine: Only on the south slopes of the sand hills is it considered advisable to plant this species, not because it will not succeed on other sites, but because these are favorable to more desirable species.

Western yellow pine: The sites in order are (1) north slopes of the sand hills; (2) ridge tops; (3) the bottoms or depressions between the hills.

Norway pine: Only the north slopes of the sand hills are considered as well adapted to the planting of this species.

No direct seeding is thought advisable in this region.

ARIZONA AND NEW MEXICO.

Western yellow pine: Approximate altitudinal limits from 7,000 to 8,500 feet. The sites in the order of their favorableness for planting or sowing are:

1. Old cuttings on western yellow-pine land. Usually such areas are practically denuded of tree growth and bear a dense growth of grass.

2. Brush land showing evidences of having been at least partly forested with western yellow pine but now occupied by a moderately dense growth of brush, such as oaks, mountain mahogany, and buck brush or cliff rose.

3. Untimbered parks or prairies within the range of the species.

Douglas fir: Approximate altitudinal limits from 8,000 to 9,500 feet. The sites in the order of their favorableness are:

1. Old burns grown up to moderately dense stands of aspen.

2. Old burns bare of aspen or other shrubs but strewn with down logs.

3. Open grass lands.

Engelmann spruce: Approximate altitudinal limits from 9,500 to 11,000 feet. The sites in the order of their favorableness are:

1. Spruce burns grown up to aspen.

2. Spruce burns not grown up to aspen but strewn with down logs.

UTAH AND SOUTHERN IDAHO.

Western yellow pine in Utah: (1) Burned-over areas in the natural yellow-pine types; (2) areas covered with brush, mainly of oak, maple, and service berry; (3) areas covered with open stands of scrubby aspen; (4) sagebrush areas.

Western yellow pine in southern Idaho: (1) Those sites producing yellow pine naturally; (2) brush areas within the limits of yellow pine and adjoining stands of that species; (3) open grassy areas in the neighborhood of timber stands.

Douglas fir: (1) Burns within the fir type; (2) sites covered with aspen of moderate density; (3) burns in the Engelmann spruce type; (4) areas covered with brush of oak, maple, service berry, cherry, and other deciduous species; (5) open grass land and mountain meadows. The planting of this species naturally centers mainly around the aspen type, particularly in Utah. The last two sites are not considered favorably for planting at present.

Engelmann spruce: (1) Burned-over, nonrestocking Engelmann spruce and balsam-fir cuttings; (2) the denser and better stands of aspen occurring at high altitudes; (3) lodgepole-pine burns.

Lodgepole pine: (1) Lodgepole-pine burns which are nonrestocking; (2) nonrestocking Engelmann-spruce burns; (3) aspen-covered areas at higher altitudes. This species is not thought suitable for planting on brush areas nor on open grassy land where sheltering objects are missing.

CALIFORNIA.

Planting has not yet progressed far enough to warrant a thorough and final classification of the sites. It has been thoroughly demonstrated, however, that sowing is a failure throughout the State and that planting can not be undertaken with any degree of success in the foothill region of southern California. At higher elevations in southern California, within the timbered belt, western yellow and Jeffrey pine are being grown successfully on open land free from rodents. The typical planting sites in this region, however, are covered with heavy brush frequented by rodents. So far the depredations of these animals have not been successfully controlled, and from present indications these depredations can not be controlled at a reasonable cost.

The planting of western yellow pine in the brush fields of northern California gives promise of very good success, and it is thought that white fir and incense cedar will also do well there. Climatic conditions during the growing season are very variable in this State and influence the degree of success in planting to a large extent. Long



F-17231A

FIG. 1.—BURNED AREA IN SIUSLAW NATIONAL FOREST, OREG. PLANTED TO DOUGLAS FIR.



F-17230A

FIG. 2.—PLANTING CAMP, SIUSLAW NATIONAL FOREST, OREG.

periods of extreme drought may occur at any time between April and November. Such a condition inevitably means a large degree of failure in new plantations. Rodents also cause heavy loss, but indications are that spring planting, use of large stock, or planting on an area immediately after it has been burned will minimize the rodent danger. Shade is of extreme importance, since it assists in preserving soil moisture.

Western yellow pine has been most successfully used between 3,500 and 5,500 feet elevation. The highest degree of success is attained under full brush shade, and a classification of planting sites may be made largely upon the basis of the shade characteristics of the brush species. The most favorable brush types are as follows, arranged in the order of their value:

1. Manzanita and snowbrush type.
2. White thorn and manzanita type.

These types are generally found at elevations over 4,000 feet. The oak and open-brush types found at lower elevations are more difficult sites, in which success can only be obtained in very favorable years.

WASHINGTON AND OREGON.

DOUGLAS FIR.

1. Areas covered with a dense growth of herbaceous vegetation in which fern usually predominates, indicating good soil and moisture conditions, mostly on the west side of the Cascades and in the Coast region at altitudes below 2,500 feet; in the Coast region of the Siskiyou Mountains at elevations under 1,500 feet. The north slopes are the best.

2. Slopes covered with a medium growth of herbaceous vegetation indicating fair soil and moisture conditions, second only to class 1; mostly on the west side of the Cascades and in the Coast region below 3,000 feet; in the Coast region of the Siskiyou Mountains between altitudes of 1,500 and 5,000 feet.

3. Sites between 3,000 and 4,500 feet in altitude on east and west slopes of Cascade Mountains. On these sites the soil may be thin and rocky, but the moisture conditions are usually good. Douglas fir should be planted in mixture with noble fir on the west side of the Cascades, and with western white pine or Amabilis fir on the east side.

4. North slopes at moderate altitudes in the Blue-Mountain region, typically cool and moist.

5. Areas below 3,000 feet on the west side of the Cascade Mountains and in the Coast region with only a scant ground cover, indicating a dry exposed situation.

6. Dense salal or brush-covered slopes in the Coast region indicating good soil and moisture conditions, but keen competition.

7. Brush-covered, northerly slopes in the eastern part of the Siskiyou Mountains at elevations of from 1,500 to 5,000 feet with soil moisture conditions variable but usually fair, and cover of California black oak, Oregon grape, manzanita, ceanothus, and willow on the better sites, and tan oak, chinquapin, huckleberry, live oak, and ceanothus on the poorer sites. Douglas fir should be planted in mixture with western yellow and sugar pines.

NOBLE FIR.

(1) Sites between 2,500 and 4,500 feet on the west side of the Cascade Mountains, except in southern Oregon. On these sites the soil may be thin and rocky, but the moisture conditions are usually good. Noble fir should be planted in mixture with Douglas fir.

(2) Sites above 4,500 feet on the west side of the Cascade Mountains. On these sites the soil is usually thin and rocky, but the moisture conditions good. Noble fir should probably be planted in mixture with *Amabilis* fir.

WESTERN YELLOW PINE.

(1) Occasional north slopes at moderate altitudes in the Blue Mountains, with good soil and moisture.

(2) Light brushy south slopes in the eastern portion of the Siskiyou Mountains with fairly good but rather warm and dry soil and a cover of tan oak, chinquapin, huckleberry, live oak, and ceanothus. Sugar pine may be planted with western yellow pine on the better soils.

(3) South slopes at low altitudes in the Blue Mountains, typically hot and dry.

(4) Serpentine slopes in the Siskiyou Mountains at an elevation of from 4,000 to 5,000 feet, with typically dry and infertile soils and a cover usually of tan oak, saddler oak, manzanita, huckleberry, knob-cone and lodgepole pines. Such sites are very difficult to plant, and it is impracticable to plant them for many years to come.

Classes of stock for planting by regions and site classes.

| Region and species. | Site class No. | Classes of stock for planting in order of their preference. ¹ | Region and species. | Site class No. | Classes of stock for planting in order of their preference. ¹ |
|---|----------------|--|---|----------------|--|
| 1. Montana and northern Idaho:
(a) East of Continental Divide— | | | 5. Arizona and New Mexico: | | |
| Western yellow pine..... | 1 | 2-0 | Western yellow pine..... | 1 | 1-1 2-1 |
| | 2 | 1-2 | | 2 | 1-1 2-1 |
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| | 2 | 2-2 | | 2 | 2-1 2-2 |
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| | 2 | 1-2 | | 1 | 2-0 2-1 3-0 |
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| | | | | 2 | 2-2 3-0 |
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| | | | | 2 | 2-1 3-0 2-0 |
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¹ The first figure of each pair indicates the number of years the stock remains in seed beds; the second figure the number of years it remains in transplant beds.

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 456

Contribution from the Office of Markets and Rural Organization
CHARLES J. BRAND, Chief

Washington, D. C.



February 5, 1917

MARKETING CREAMERY BUTTER

By

ROY C. POTTS, Specialist in Marketing Dairy Products, and
H. F. MEYER, Assistant in Marketing Dairy Products

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 459

Contribution from the Bureau of Animal Industry
A. D. MELVIN, Chief

Washington, D. C.



December 15, 1916

THE USE OF ENERGY VALUES IN THE
COMPUTATION OF RATIONS
FOR FARM ANIMALS

(A REVISION OF FARMERS' BULLETIN 346)

By

HENRY PRENTISS ARMSBY

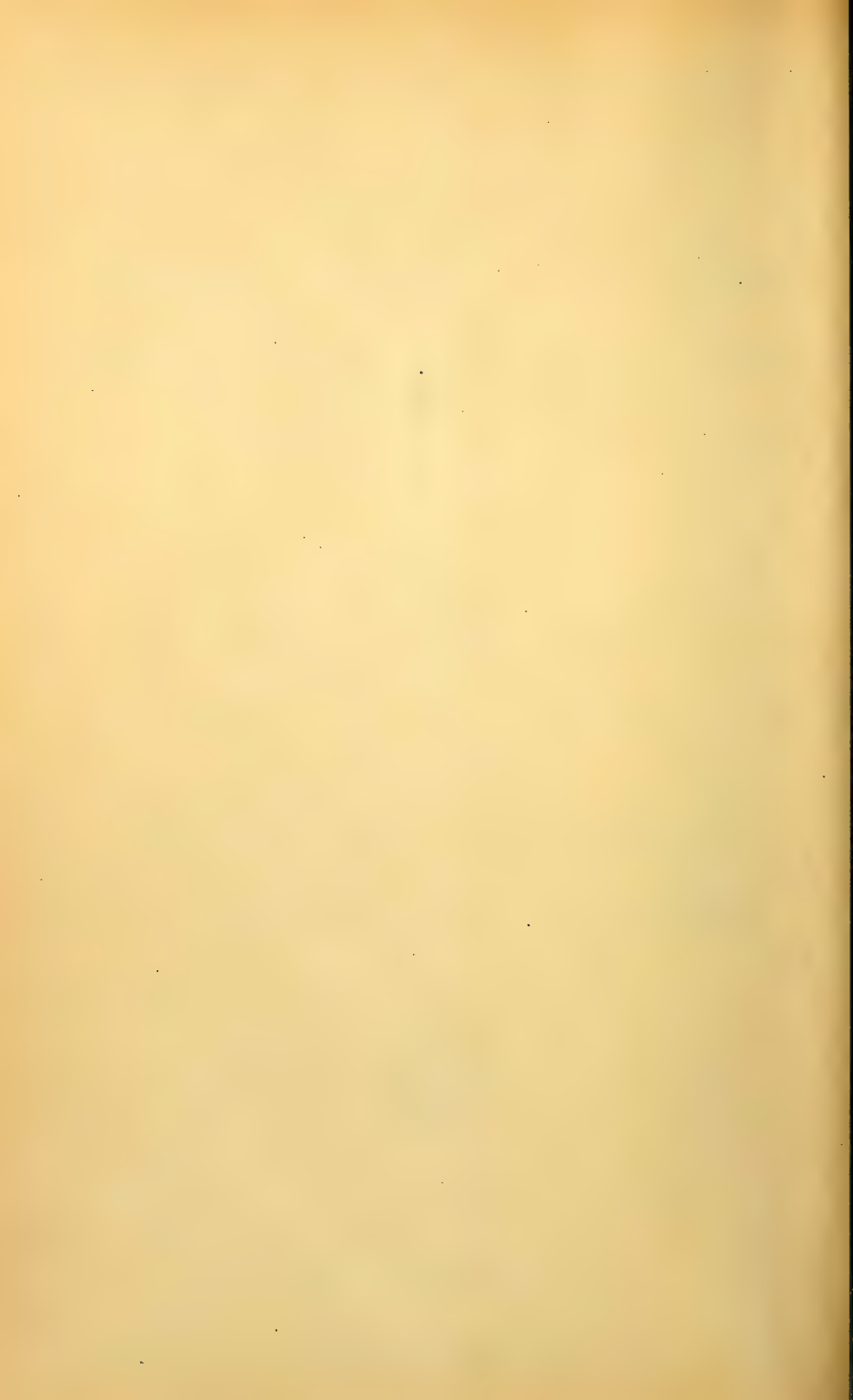
Director of the Institute of Animal Nutrition of The
Pennsylvania State College; Expert in Animal
Nutrition, Bureau of Animal Industry

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 460

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C.

PROFESSIONAL PAPER

May 26, 1917

THE PINE TREES
OF THE ROCKY MOUNTAIN REGION

By

GEORGE B. SUDWORTH, Dendrologist

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 462

Contribution from the Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director

Washington, D. C.



February 16, 1917

IRRIGATION IN FLORIDA

By

F. W. STANLEY, Irrigation Engineer

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 463

Contribution from the Office of Public Roads and Rural Engineering
LOGAN WALLER PAGE, Director

Washington, D. C.



February 21, 1917

EARTH, SAND-CLAY, AND
GRAVEL ROADS

By

CHARLES H. MOOREFIELD, Senior Highway Engineer

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 466

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief

Washington, D. C.

PROFESSIONAL PAPER

November 3, 1917

MAPLE SUGAR
COMPOSITION, METHODS OF ANALYSIS,
EFFECT OF ENVIRONMENT

By

A. HUGH BRYAN, Formerly Chief, Sugar Laboratory, in
Collaboration with M. N. STRAUGHN, C. G. CHURCH,
A. GIVEN, S. F. SHERWOOD, Assistant Chemists

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 468

Contribution from the States Relations Service
A. C. TRUE, Director

Washington, D. C.

PROFESSIONAL PAPER

January 17, 1917

POTATOES, SWEET POTATOES, AND
OTHER STARCHY ROOTS AS FOOD

By

C. F. LANGWORTHY, Chief, Office of
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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 473

Contribution from the Bureau of Crop Estimates
LEON M. ESTABROOK, Chief

Washington, D. C.



February 12, 1917

PRODUCTION OF SUGAR IN THE UNITED STATES AND FOREIGN COUNTRIES

By

PERRY ELLIOTT, Division of Crop Records

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 475

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C.

PROFESSIONAL PAPER

May 28, 1917

REFORESTATION ON THE NATIONAL FORESTS

By

C. R. TILLOTSON, Forest Examiner

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ALBERT F. POTTER, Associate Forester.

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EARLE H. CLAPP, *Assistant Forester in charge.*

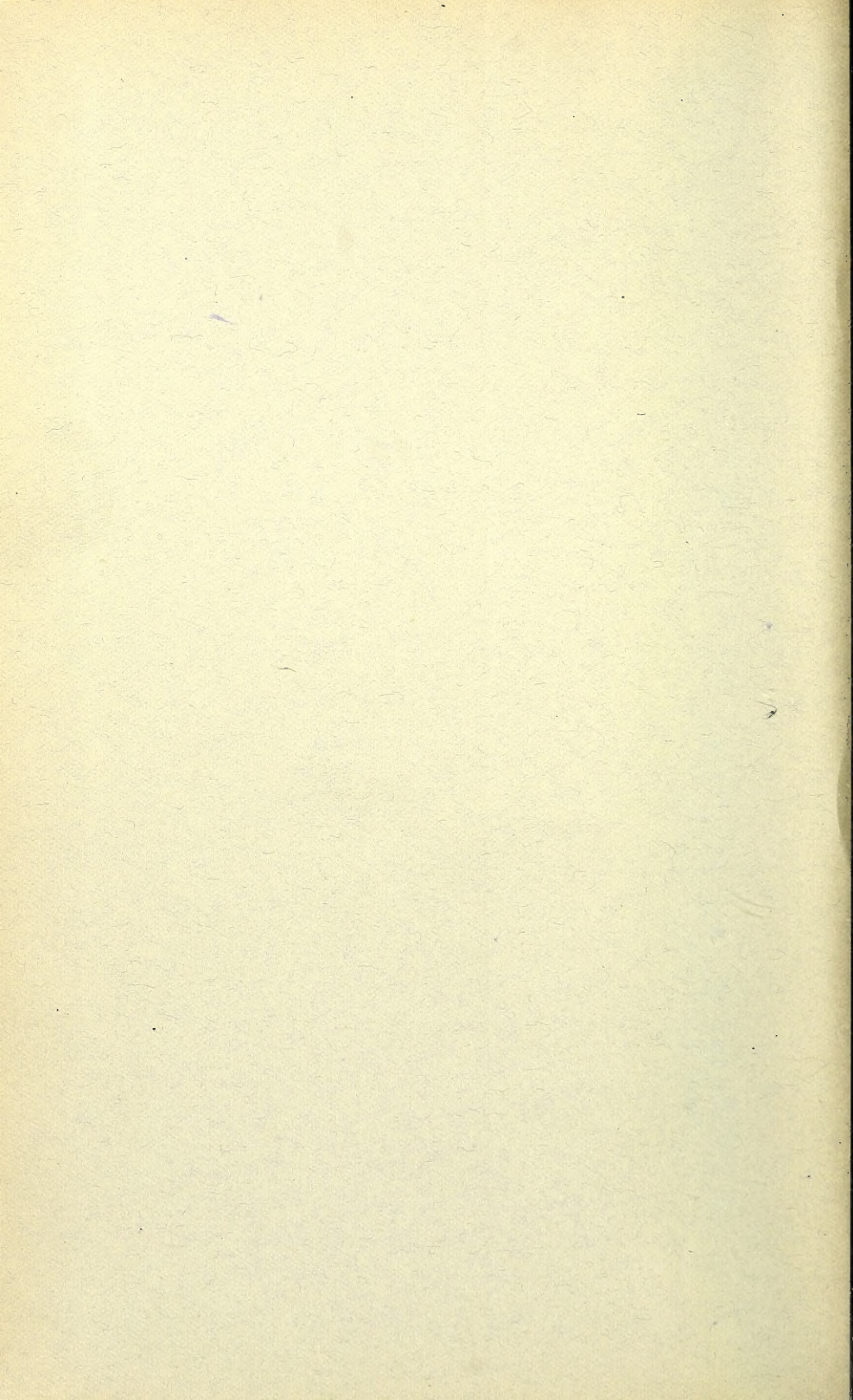
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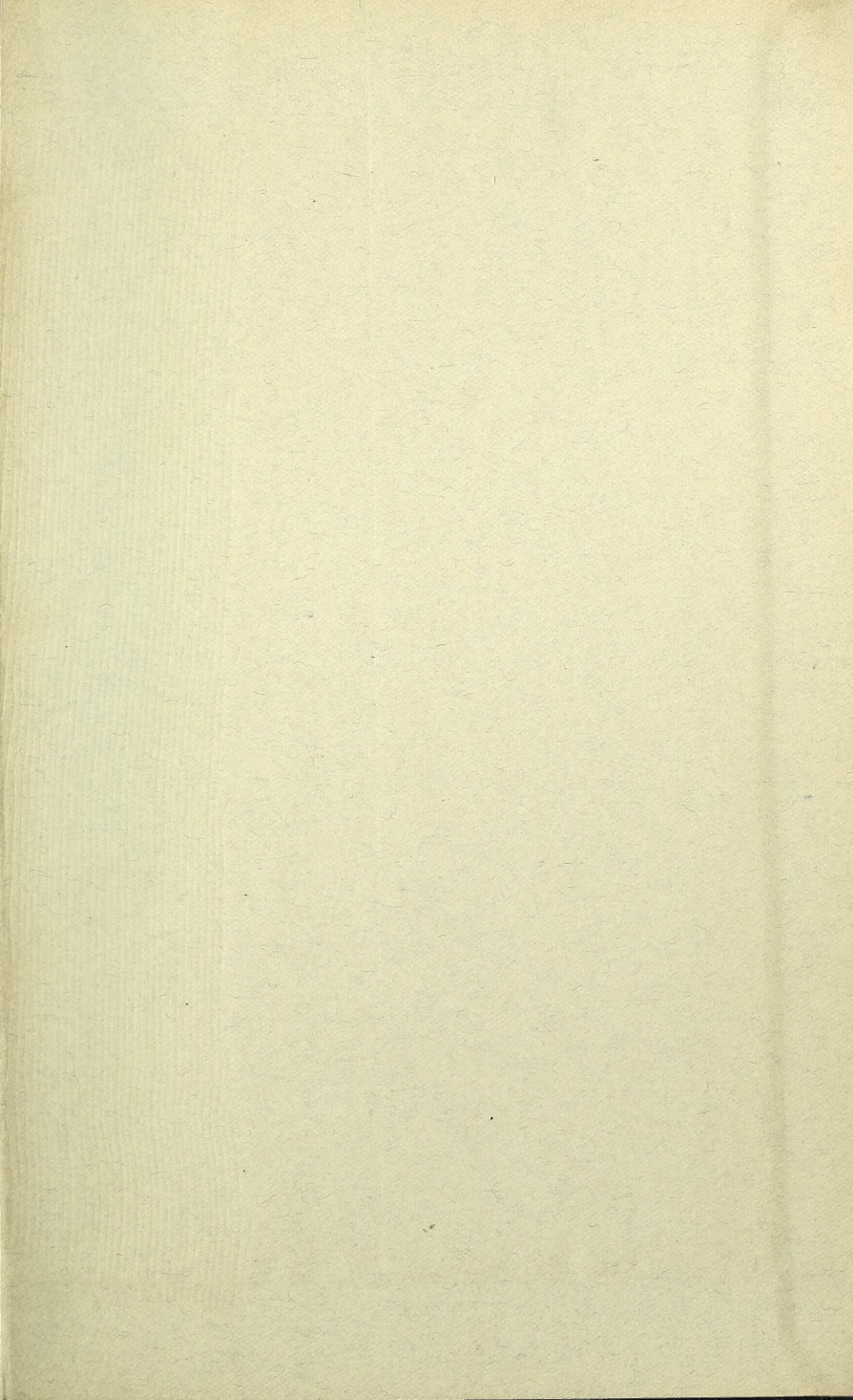
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